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THE

OPERATIVE MECHANIC,

AND

BRITISH MACHINIST;

BEING

A PRACTICAL DISPLAY

OF

THE MANUFACTORIES AND MECHANICAL ARTS
OF THE UNITED KINGDOM.

BY JOHN NICHOLSON, ESQ.
CIVIL ENGINEER.

Second American from the Third London Edition, with Additions.

IN TWO VOLUMES.
VOL. I.

Philadelphia:
T. DESILVER, JUN. 247 MARKET STREET.
James Kay, Jun. & Co. Printers.
1831.

Eastern District of Pennsylvania, to wit:

Be it remembered, that on the first day of November, in the fifty-fifth year of the independence of the United States of America, A.D. 1830, T. Desilver, Jun. of the said district, has deposited in this office the title of a book, the right whereof he claims as proprietor, in the words following, to wit:

The Operative Mechanic, and British Machinist; being a Practical Display of the Manufactories and Mechanical Arts of the United Kingdom. By John Nicholson, Esq. Civil Engineer. Second American from the Third London edition, with additions. In two volumes.

In conformity to the act of the congress of the United States, entitled, "an act for the encouragement of learning, by securing the copies of maps, charts and books to the authors and proprietors of such copies during the times therein mentioned;" and also to the act, entitled, "an act supplementary to an act, entitled, 'an act for the encouragement of learning, by securing the copies of maps, charts and books to the authors and proprietors of such copies during the times therein mentioned,' and extending the benefits thereof to the arts of designing, engraving and etching historical and other prints."

D. CALDWELL,
Clerk of the Eastern District of Pennsylvania.

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TO

GEORGE BIRKBECK, ESQ. M.D.

PRESIDENT OF THE LONDON MECHANICS' INSTITUTION,

&c. &c. &c.

SIR,

IN an age like the present, when the rich and the powerful identify their interests with the welfare of the poor and uninformed, when the wise and the good combine in furthering the diffusion of sound principles and useful knowledge among those who constitute the most important, though hitherto the most neglected, portion of the community, there is not one who can view the future in the past but must anticipate with such data before him, a change as brilliant in its effects, as it is honourable to those who are engaged in promoting it.

The advanced state of science, and the comprehensive views of a just and liberal philosophy, animate those who for many years have compared theory with practice to come forward in the hope of being able to offer something in aid of the common cause.

Such feelings, Sir, have encouraged me to publish the following pages, which, as an earnest of their future success, I am permitted to dedicate to yourself.

A work of this kind, combining in the most condensed form the acknowledged principles and recent improvements in Mechanical Science, and professing to be adapted in every possible way to the use of the Mechanic and Machinist, could not well find a Patron more congenial to its Spirit than one, who, during a long series of years, has laboured with no common devotion in promoting their benefit.

I am,

Sir,

Your most obedient, and

Much obliged humble Servant,

JOHN NICHOLSON.

INTRODUCTION

AND

GENERAL OUTLINE PLAN

OF THE

Operative Mechanic.

THE discoveries of WATT and ARKWRIGHT, which yielded at once such immense national as well as individual prosperity, must ever be regarded as forming a new era in the arts of life and the domestic policy of nations. The riches, extraordinary as unprecedented, inexhaustible as unexpected, thus acquired by a skilful system of mechanical arrangement for the reduction of labour, gave the impetus which has led to the numerous discoveries, inventions, and improvements, in every department of our manufactures, and raised them to their present state of perfection.

With respect to our primary and most elaborate pieces of mechanism, however intricate and incomprehensible they may appear to the inexperienced, they are in the eye of the practical man mere elegant modifications and combinations of a few simple principles. These principles, after some necessary observations on the Forces acting on Matter, on Friction, and the Centre of Gravity, are fully elucidated in the account of "THE MECHANICAL POWERS."

These are followed by what is indispensably necessary to the proper construction of Mill-work, viz. a description of BEVEL and SPUR GEER, the longitudinal connexion of Shafts, termed COUPLING, the most approved method of DISENGAGING AND RE-ENGAGING MACHINERY, and of the EQUALIZATION OF MOTION, with some general Practical Observations, given under the article "MILL GEERING."

The reader who attentively peruses these articles will be in possession of the primary points of MILL-WORK; we have, therefore, next introduced to his notice, under ANIMAL STRENGTH, WATER, WIND, and STEAM, the best modes of applying the MOVING POWERS; and to them is annexed a short, though concise, account of ***Brown's Vacuum or Pneumatic Engine***, which may with improvements be made most effective for locomotion and other light purposes.

As the reduction of wheat into flour forms so essential a part of domestic œconomy, and as the force which gives a rotatory motion to the upper mill-stone is almost invariably imparted either by wind or water, we have thought it no deviation from scientific arrangement, to introduce at the end of these two articles a description of a FLOUR-MILL; as, by that means, the reader will be enabled to form a tolerably correct notion of the manner of imparting motion from the water-wheel, or leader, to the other parts of machinery. And while upon this subject we have, with a view to make the work generally useful, described the hand and foot methods of grinding corn, that those who live not in the vicinity of a mill, or who do not choose to submit to the impositions said to be practised by many millers, may, at a comparatively trifling expense, have the work performed at home.

A knowledge of the STRENGTH OF MATERIALS being at all times important in the construction of Mill-work, more particularly in those parts which have to sustain the greatest force, or put the whole of the other parts of the machinery in motion, we have, next to the Moving Powers, inserted a letter from Mr RENNIE, jun. to Dr. YOUNG, describing a series of very satisfactory experiments made on this subject.

A description of HYDRAULIC ENGINES next follows; and these are succeeded by certain SIMPLE MACHINES acting as accessories to our manufactures. So that, by the time the reader has advanced thus far, he will have become so thoroughly intimate with machinery, as easily to comprehend and appreciate the several excellencies of our STAPLE MANUFACTURES, which are next unfolded to his view.

The whole was intended to be concluded with an examination of those arts termed MANUAL, in a treatise on the Art of Building; except, indeed, with the addition of an Appendix containing a short and concise treatise on PRACTICAL GEOMETRY and MENSURATION, with a Collection of approved RECEIPTS, and a GLOSSARY; but the interest which has lately been excited respecting RAILWAYS and LOCOMOTIVE ENGINES has led to the extension of the work, about thirty pages, with an article on those constructions.

Although there are several very excellent treatises on Mechanics and Mill-work now extant, yet, presuming on an arrangement widely different to that of others, by which the least erudite and most inexperienced may acquire something more than a mere Superficial Knowledge of Machinery, the Author trusts that the following pages will meet with a favourable reception.

In the course of his labours he has derived material assistance from many of his scientific friends, to whom he thus publicly expresses his acknowledgments; and more particularly to that Gentleman to whom the volume is dedicated.

In a work of such a nature it is generally understood that extracts are justified, as the description of many things not new are requisite, and the language could not in general be improved. In such cases, however, the authority has, in general, been acknowledged, and in a way calculated to advance the honour and interest of every improver and discoverer.

The volume in its design and execution is offered as a companion to THE WORKSHOP, consequently abstract and theoretical principles have been allowed to mingle no further than has been indispensably necessary to the perfect illustration of the use and application of the object described. The work has, therefore, no similarity to the Mathematical Illustrations of WOOD, GREGORY, or EMERSON, each of which, and more particularly that of Dr OLINTHUS GREGORY, deserves to be spoken of with great respect.

A book comprehensive and practical, embracing the whole subject as living and contemporaneous, and as connected with private profit and public glory, instructive to individuals and illustrative of the genius of the age in its best direction, has been the object of the Author, and *he* hopes he has not laboured in vain.

LONDON,
March, 1825.

ADVERTISEMENT

TO

THE SECOND AMERICAN EDITION.

The publisher presents the second American edition of Dr Nicholson's very valuable work, with the improvements contained in the second London edition. Considerable additions have been made to the text, and several new plates have been inserted. In the London edition there were numerous errors in the references from the text to the plates, all of which it is believed will be found to be corrected in this edition, in which have also been added references from the plates to the text, an addition which will be appreciated by all who have frequent occasion to consult the work.

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DESCRIPTION OF THE FRONTISPIECE.

This Plate represents a front view of a Steam-engine connected with a Sugar-Mill, as constructed by Messrs Taylor and Martineau, who have kindly permitted our draftsman to make a drawing of it.

This Engine, being only twelve times larger than the drawing, is, from its compactness and simplicity of construction, peculiarly applicable to most of the manufactures round the metropolis, where power of a moderate amount is in general required.

It works horizontally, at from 30 to 40 lbs. pressure per square inch, without condenser, having metallic pistons and slide-valves, and only requires eight screw-bolts to fasten it to oak sleepers, or frame-work of moderate scantling.

A is a crank connected with the piston-rod, which, as it works in the cylinder horizontally, cannot be seen. B is the cylinder, into which steam is admitted from the boiler, by means of the pipe C C C. The amount of steam flowing into the cylinder is regulated by the throttle valve at D, which is opened and shut at proper intervals by the rod E E E. F F is the governor, or regulator, consisting of two heavy balls, with the sliding collar *a*, suspended from the top of a vertical spindle *b b* at the axis *c*. This spindle is connected with the main shaft, by a strap passing over the sheeves or pullies, G G G, which cause it to revolve; and as its speed varies with that of the main shaft, the governors F F, according as its speed increases or decreases, have a tendency either to fly from, or approach to, the spindle. This rise or depression of the governor affects the rod E E E, to which it is connected, and regulates the quantity of steam flowing from the boiler into the cylinder.

H is a piece to connect the top part of the piston-rod with the rod I, so that by the motion of the crank the rod I is also moved, which rod moves the slide valves in the cylinder K. By the action of these valves, steam is alternately admitted on the opposite sides of the piston; and as the engine does not condense its steam, there are two pipes, placed one at each end of the cylinder, to carry it off. One of these pipes is seen at N. When the piston has been driven by the force of the steam to the other extremity of the cylinder, the steam, by the action of the slide valves, is shut off from this end, and allowed to flow into the opposite end of the cylinder; the orifice of the pipe N being at the same time opened, the steam at this end is, by the returning action of the piston, driven through the pipe N, and conveyed away under ground, leaving this end of the cylinder ready for a fresh supply.

The power generated by this simple arrangement is made to effect the required purpose by means of the shafting O O O. On this shafting, at a little distance from the engine, is an eccentric, L, to raise the rod M, to pump water into the boiler when required: and at nearly the further end of the shafting is another eccentric, W, which imparts motion to the rod V, for the purpose which we shall hereafter describe.

The rotatory motion which the crank has received from the engine is imparted to the shafting, to the eccentric L, the coupling-box *d*, the fly-wheel P, the eccentric W, and the pinion Q, which plays in the large cog-wheel, R, on the shaft S, and thence is imparted to the rollers of a sugar-mill, which rollers are moved at equal speeds by the pinions U U.

In this, and most other Sugar-mills, there are three rollers, two at the bottom, and one lying between the other two at the top. Through these rollers sugar-canes are passed, and the compressed juice falls into a receiver, from whence it is pumped, by the movement of the rod V, into a copper, or other receiver. At that part of the shafting marked *e e*, sufficient space is left to allow of play when the canes are passed through the rollers, otherwise the shafting would be very apt to snap and be destroyed.

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N. B. The author would advise such of the purchasers as intend to have the work bound, to have the plates put in a separate volume.

* Plates 67 and 68, and plate 96 and plate 98 must be guarded.

ERRATA IN VOL. I.

Page 61 line 12, for H, read A.
" 63 line 17, 19, 25, for left, read right.
and line 18, for right read left.
" 112 line 4, for 116, read 94.
" 174 line 15, for F M, read f m.
" 278 line 25, for 271 read 272.
" 302 in line 11, add, and 302, a side view.
" 303 line 9, 10, and 26, for 301 read 302.
" 304 line 29, for 302, read 301.
" 330 line 32, for 306, read 308.
" 406 line 4, for 425, read 426.
" 410 to line 25, add, fig. 436.

THE
OPERATIVE
MECHANIC AND MACHINIST.

OF THE ACTION OF FORCES.

ALL matter is continually under the operation of forces, which, if acting upon it equally, and in opposite directions, maintain it in a state of rest. But if a newly created force act upon a body in such a direction, and to such an extent, as to overcome the forces under whose action that body, in common with all other matter, exists, the result will be motion communicated to that body; and in an exact proportion as that newly created force exceeded the amount of forces that were previously acting upon it in the opposite direction. For example, if a man lift a pound weight three feet from the ground, the amount of motion created by that action is exactly equal to the amount his newly created force exceeded the force of gravity or weight which acted on the matter: for if his force had not exceeded the force of gravity, it is manifest that that motion could not have been created; and if the force of gravity had not existed, it is again manifest that the amount of motion would be exactly in proportion to the amount of the whole of the force he had applied. Again, if his force only exactly equalled, and did not exceed the force of gravitation, motion could not have taken place, and the body would have remained at rest.

This state of rest, maintained by the contrary action of two equal forces upon a body, is called *equilibrium*. But the term equilibrium is most commonly applied when one or more bodies are, by the mere force of gravitation, maintained in a state of quiescence, or rest: thus, if a bar of iron, A B, fig. 1, is supported at its centre C, it will balance, or remain horizontal, as the quantity of matter in C A is exactly equal to that in C B, and the amount of the gravitating force proportional to the quantity of matter that is in each arm of the bar: likewise, if a ball, A, fig. 2, be acted upon by a force at B, and by another force, exactly equal, at C, the ball A will be maintained in a state of quiescence, termed equilibrious.

In the common operations of mechanics, the former state of equilibrium frequently occurs; the latter rarely, and never with any permanent duration; by the term equilibrium, therefore, in general, is understood, the position first cited.

Upon duly considering that matter, when between forces acting in opposite directions, is in a state of equilibrious quiescence, it will be manifest, that motion cannot be obtained without destroying the equilibrium. It must not therefore be supposed, that the forces of gravitation or adhesive attraction can produce motion, as has been erroneously urged by some, but rather that all the motion these powers are capable of producing was primarily exerted to bring matter into that state of equilibrium in which we find it. Wherever that equilibrium is disturbed by extraneous causes, the resultant motion, attainable by such disturbance of the general equilibrium, has long since been known, and applied to useful purposes. We may with propriety, therefore deduce from these considerations, the perfect fallacy of that most ruinous and speculative notion of a perpetually moving force. Many who have wasted their time in attempts to attain that object, have either supposed that the force of gravitation could obtain motion, or that motion once obtained could of itself increase its force; which was about as rational as to suppose that any substance could of itself increase its own bulk. The powers with which nature has supplied us, have, as far as we are aware of, been already applied; and should there be others existing of which we are ignorant, or which we have not reduced to our command, the search for, and development of such objects, are praiseworthy and valuable: but let us with confidence hope, that the labours of ingenuity will no longer be drawn aside from the paths of prolific study, by this destructive phantasy.

Returning from this digression, when a body is operated upon by a force, and acquires motion, that motion, taking into account the amount of space through which the body passes in a given time, is called *the velocity of the body;* and according as the extent of distance increases or decreases in a greater or less period of time, the velocity is said to increase or decrease.

If a force acting upon any body, and causing motion, shall continue to act upon it in the same direction, so as to continue to increase that motion, the body, under such circumstances, is said to attain *accelerated velocity*. And

MECHANICAL POWERS

From 1 to 17

Fig. 1.p.1.

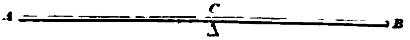


Fig. 2.p.1.

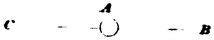


Fig. 3.p.3.

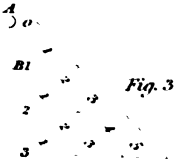


Fig. 4.p.5.

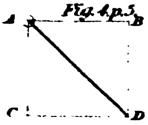


Fig. 5.p.5.

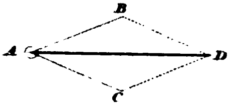


Fig. 6.p.5.

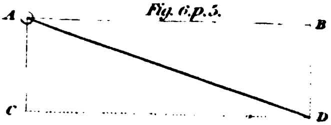


Fig. 7.p.5.

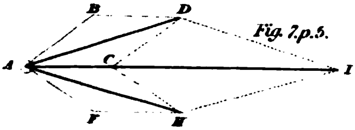


Fig. 8.p.5.

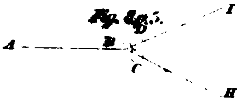


Fig. 9.p.6.

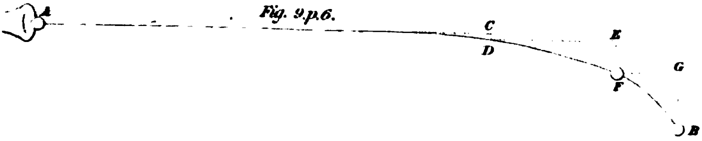


Fig. 12.p.7.

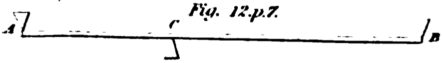


Fig. 11.p.6.

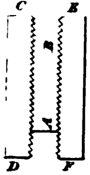


Fig. 10.p.6.

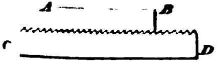


Fig. 14.p.10.

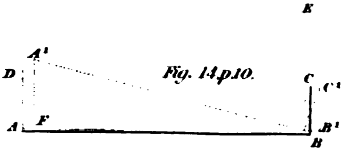


Fig. 13.p.9.

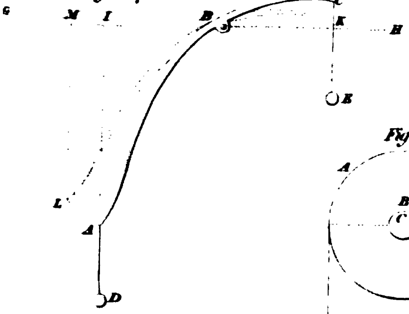


Fig. 15.p.10.

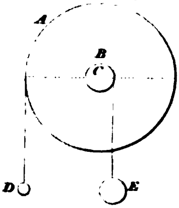


Fig. 16.p.11.

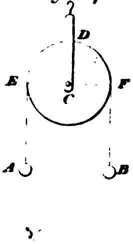
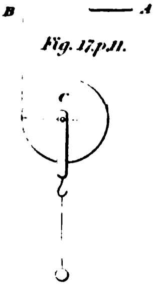


Fig. 17.p.11.



if a body be put in motion by a certain force, and another force operate upon it in a contrary direction, so as to tend to bring it to a state of equilibrium, such motion is called retarded motion.*

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* The simplest example of accelerated motion, is exhibited in the action of the force of gravitation upon a falling body, where the force continues to act during its descent, and regularly increases in velocity; so that if a body A, fig. 3, be allowed to fall from that position towards the earth, it will pass through sixteen feet during the first second of time, forty-eight feet during the next, and eighty feet during the third. Had its motion been regular during these three seconds of time, it would have passed through only three times sixteen, or forty-eight feet, whereas it has passed through one hundred and forty-four feet by reason of the force which first caused its motion continuing to act upon it. Now as its velocity increases regularly, we may conclude, that during the performance of the first half of the sixteen feet, it was not proceeding at the rate of sixteen feet per second; and if we suppose it was proceeding only at half that velocity, then it must have travelled through the second half at the rate of thirty-two feet per second; or, if the first eight feet took three-quarters of the second, the second eight feet must have been performed in the remaining quarter, therefore, when the body arrived at B, it would be proceeding at the rate of thirty-two feet per second; to which, if we add the force that continues to urge it at the rate of sixteen feet per second, it will exhibit, for the second space, a velocity of forty-eight feet per second: and if for the third space we double its increasing velocity of thirty-two feet, and add that created by the continued force, we shall have twice thirty-two, and sixteen, are eighty, which is the result of experiment. The velocity of bodies under the continuous action of any given force, will, it appears, increase as the odd numbers 1, 3, 5, 7, 9, &c. that is, sixteen feet during the first second, thrice sixteen feet during the next second, five times sixteen during the third second, and so on; or, as the relative portions of the superficial space under equal parts of the perpendicular in a right angled triangle, as represented at fig. 3: where 0 to 1 represents the first second of time, 1 to 2 the second, and 2 to 3 the third. It will be perceived, that under each of these portions, the space contained in the triangle will be as 1, 3, 5; such is uniform accelerated motion. But if the continuous force, which has been shown to increase the velocity, vary in its action upon the body, it is plain the increase will be no longer uniform.

From a clear comprehension of the acceleration of motion in bodies, the retardation of motion will be easily conceived: for example, if a body be cast perpendicularly from the earth, as in the firing of a shot from a cannon upwards, the force of the powder, overcoming the force of gravitation, will cause the ball to rise with a certain velocity, whilst that attraction continuing to operate in the opposite direction, checks by regular gradations the created force, and eventually destroys it. Thus the distance which the shot would have accomplished during the first second of time, is reduced by sixteen feet; that which it would have accomplished during the next second, by forty-eight; and so on until the created power is counterbalanced by the force of gravity, and the ball arrives at a state of rest; when the force of gravity acting upon it solely, will cause it to move in the opposite direction, till it descends to the earth.

When a ball attached to a centre by a flexible cord, is put in motion by any one force, which, in common with all other forces, acts in a right line, the motion will be circular. The tendency which such body has to fly from the centre, is called the centrifugal force; and that exerted by the cord to draw it towards the centre, the centripetal force.

When a body is set in motion by any force, it is enabled, to a certain extent, to act on other bodies, and create motion in them; and as the velocity it obtained was as the power expended to create that motion, so is the power of transmitting that motion to its velocity. This power of communicating motion, or, in other words, this force possessed by matter in motion, is termed *momentum*, or the moving force; and the mode of transmitting it *impact:* as this force is proportional to the velocity possessed by every particle of matter composing any body, the momentum must be represented by the quantity of matter multiplied by its velocity. For instance, suppose one hundred particles of matter were moving at the rate of one foot per second, the power requisite to overcome their force is exactly the same as that which would be necessary to arrest the motion of one particle moving at the rate of one hundred feet per second: for the velocity of the hundred particles being one foot per second each, their total force would be the force existing in one of them multiplied by one hundred: and again, as the force is in proportion to the velocity, one particle moving at the rate of one foot per second, multiplied by one hundred in regard to velocity, will produce a similar result. Also, if a body of one pound weight be moving at the rate of one foot per second, it will possess a certain *momentum*, and if either its weight or its velocity be doubled, its momentum will be likewise doubled: if both be doubled, the momentum will be quadrupled.

Having now considered the action of one and two forces acting together in opposite and similar directions, we will proceed to examine the action of two forces upon a body, acting neither in the same, nor in contrary directions. Thus, if the line A B, fig. 4, represent a force sufficient to carry the body A to the point B, and A C represent another force sufficient to carry the body A to the point C, then A C and A B being equal to C D and B D, and those two forces act upon the body subsequently to each other, we may conceive that the body would, by passing over the lines A B and B D, or A C and C D, be carried to the point D. Now, if they act upon the body at the same instant, the result will be the same, and the total expenditure of the forces will place the body, passing by the line A D, at the point D. Likewise, if the forces A B and A C be not at right angles, as in fig. 5, still as C D and B D are equal, and in similar directions to A B and A C, the motion received from them by A will be represented in amount and direction by the line A D. But supposing A B shall be twice or thrice the power of A C, then the effect will be the same as is shown in fig. 6, where the line A B represents thrice the power of A C. The separate actions of A B and A C will be represented as before by B D and C D, which would place the body A at the point D; therefore their combined force will cause it to pass by the diagonal line A D, as in the former instance. This proves that any number of forces acting upon a body in however many lines, not directly opposite to each other, will be *compounded* into one force: for suppose three forces, A B, A C, and A F, fig. 7, to operate in their several directions at the same instant, on the body A, they will be compounded into the force represented by A I; for if we describe a parallelogram as before by the lines A B and A C, those two forces will be compounded into a force represented by A D; and again, if we do the same with the two forces A C and A F, we shall have the force A H composed of them. We have therefore two forces A D and A H compounded of the three original forces. If we proceed with these two in the same manner, they will be compounded into the force represented by A I; D I and H I completing the parallelogram of which A I is the diagonal: so that any number of forces acting in any number of directions, excepting in opposite ones, may be compounded into one, which is termed their *composant*, and which is always represented by the diagonal of a parallelogram, like that already shown.

The resolution of forces is exhibited by reversing this problem; for as any number of forces may be combined into one force, so may one force be resolved into any number. If a single force be represented by a ball moving with a certain velocity in the direction of the line A B, fig. 8, when it shall come in contact with and act upon the balls C and D, these two balls will each of them move with one half of the velocity with which B was impelled, and in the direction of the lines C H and D I, drawn from the centre of B through each of their centres: so that if the force of B be divided into two equal portions, each of those portions may, by a similar process, be again divided, *resolving* the original force to infinity.

The next effect of forces upon bodies producing motion, is that in which a body receives motion from one force, whilst it is under the continuous action of another force, not acting upon it in an opposite direction. Suppose the ball A, fig. 9, to be ejected from the mouth of a cannon, the instant it has left it at A, it will be under the influence of the force of gravitation, which will cause it to descend towards the earth in the manner already shown when speaking of accelerated motion, and ultimately will bring it to a state of rest at the point B: for supposing that the ball, by the force of the powder, leaves A, and travels in the first second of time a given number of feet, expressed by the line A C, the gravitating force during such action will cause it to descend sixteen feet, expressed by the line C D; and during the next second, supposing the powder to have impelled it the distance expressed by the line D E. the gravitating force will cause it to fall forty-eight feet, as is shown by E F; and during the next portion of its horizontal motion, expressed by F G, its descent by gravitation will amount to eighty feet, represented by G B. The line, therefore, in which the body would move when acted upon by these two forces only, would be that of a parabolic curve; but as the resistance of the air is to be taken into account in all practical cases, the line of motion changes very considerably, and assumes one that involves a problem of exceeding complexity; which, together with many other results of the effects of combined forces, is of such intricacy as to demand much more room for their solution than the limits of this work will permit us to give.

OF FRICTION.

The surfaces of bodies, however smooth they may appear to be, will be found, upon a minute inspection, to possess certain irregularities: so that if the body A B, fig. 10, have to move upon the surface of the body C D, and the lower surface of A B possesses prominences which enter into cavities in C D, it is manifest that A B cannot be moved along unless it either rises and falls the height of the several prominences, or breaks them off: in the first, it will have to overcome the attraction of gravitation; in the second, the attraction of cohesion. Again, if the body A B, fig. 11, be placed between C D and E F, which are pressed against its sides by any applied force, and their surfaces be similar to those in the former instance, to effect the movement of A B, the attraction of cohesion must be overcome, as before shown, or the applied force must be conquered. Such is the almost universal nature of that resistance called friction; for although the irregularities upon the surfaces of bodies are by no means so manifest as those here represented, still, upon minute examination, we are enabled to discover that the smoothest surfaces contain them; and as the amount of resistance increases in direct proportion as the irregularities present themselves, we are warranted in concluding that all resistance arising from friction owes its origin solely to this cause.

OF THE MECHANICAL POWERS.

The mechanical powers are six in number, the LEVER, the WHEEL and AXLE, the PULLEY, the INCLINED PLANE, the WEDGE and the SCREW. A perfect knowledge and thorough appreciation of which should be clearly understood by those who purpose to examine into the effects of mechanical combinations; the whole of which, however intricate, originate from, and are reducible to, one or more of the laws which govern these simple machines.

In demonstrating the mechanical powers, that which is not strictly true must be admitted: the force of gravitation, the retardation of friction, the resistance of the atmosphere, and the irregularity arising from the partial elasticity of the substances of which they are formed, must be excluded, and supposed not to exist.

The first-mentioned power is the *lever*, which is divided into three classes. In fig. 12, A B is a lever, and C the fulcrum, or immovable point on which it rests: now, if a force be applied at B, and the resistance, or the force or weight to be overcome, is at A, then, with the fulcrum so situate between the forces, it is called a lever of the first class; and the operation of the force at B to overcome the resistance at A, will be in proportion as the distance A C is to the distance B C; that is to say, if B C be four times the distance of A C, the force applied at B will be exactly equal to four times the same amount of force at A; or one pound weight at B will counterbalance four pounds weight at A; but to whatever height (suppose one foot) the weight at A be raised, B must descend four times that space, and consequently, to place B in its original position, the force applied must be equal to the raising of four single pounds one foot each, which is the same as the raising of four pounds one foot, as was effected at A.

An actual gain of power does not exist, but the gain in convenience is great; for, by the operation of one pound, four pounds is moved, which, but for the invention of the lever, could not have been effected. A man whose utmost strength could lift no more than one hundred and fifty pounds is by this means rendered capable of giving motion to four times that weight, although he is obliged to exert his strength through four times the distance. A lever of the second class may be represented by supposing A to be the fulcrum, B the force applied, and C the weight, or resistance to be overcome. The effect of this lever must be estimated by comparing the distances C B to A B; the power will increase or diminish exactly in proportion as A B exceeds C B, and the distance that B moves through will increase exactly in the same proportion.

Suppose, in reference to the same figure, C to be the force applied, A the fulcrum, and B the resistance, it will then represent a lever of the third class. The effect of levers of this class is to lose power for the purpose of gaining either motion or distance. For if in the last mode, the power applied at B increased as the length of A B became greater than C B, it is plain that in the present case, the resistance at B is placed in a position to gain by the same law: therefore, the nearer the force is placed to B the greater will be the effect, and when applied at B, the greatest; but when the force is at B, it is applied direct to the resistance, and the lever is abandoned; consequently C, in every position between A and B, loses power to a greater or less extent. As the movement of C, in the last case, was one-half that of B, so in the present case will the movement of B be twice that of C.

In particular operations, levers of each of these classes have their particular uses. The simplest application of the first sort may be seen in scissors, shears, forceps, &c. the pin in the joint is the fulcrum, the hand is the force applied, and the substance to be cut or pinched is the resistance to be overcome; the second sort of lever is presented to us in the cutting knives used by last makers, where the hand is the power, the ring into which the other end of the knife is hooked is the fulcrum, and the object to be cut is the resistance. Common fire-tongues are levers of the third class, as they possess a capability of being extended at the extremities: in using them the motion of the hand produces, perhaps, six times its own motion in the extremities, and a loss of power exists in a similar proportion; but as they have to be used only for a short period, the loss of power is of less importance than the convenience gained. This last class of lever is frequently introduced in machinery, for the purpose of obtaining a rapid motion; and as the same object has been aimed at in the construction of almost all animals, we find that nature has introduced it most frequently.

We have considered the operations of the lever by the different dispositions of the acting and resisting forces and the fulcrum, under the supposition that the lines of the direction of the forces were at right angles to the arms on which they operated, or formed tangents to the arcs which the movements of those arms described; but if we alter the form of a lever from that of a right line, and the two forces still maintain their parallel direction, the action on their respective arms will be no longer at right angles, and their effects will in consequence be varied; the mode of estimating those effects must be also changed. Fig. 13, A B C represents a bent lever resting upon its fulcrum B, and having appended to each of its arms the weights D and E, which are equal to each other and in equilibrium, notwithstanding the arm B A is longer than the arm B C. Draw the horizontal line G H, passing through the fulcrum B, then the weights D and E acting in perpendicular lines, we may imagine that D is suspended at the point I, and E at the point K, at which points they will operate similarly. Suppose K I to be the lever, the arms I B and B K will then be equal, and if their distances are multiplied into E and D, which are equal forces, their effects will be equal. The action of parallel forces upon levers, that do not receive the action at right angles to their respective arms, should be estimated by the force multiplied into a line drawn from the fulcrum, perpendicular to the line of direction of each respective force; and whatever may be the form of the lever, it is apparent, that, if the lines of direction vary from being tangents to the arcs described by its arms, their effects must be estimated by the length of perpendiculars let fall upon the lines of direction in a similar manner. Recurring to fig. 13, it will be seen, that if the arm B A rise to the position B L, the perpendicular B I, if allowed to fall upon the line of direction, will be increased from B I to B M, and that the effect of the force D over E will be augmented. This peculiarity is brought into operation in a balance that has a graduated scale on an arc, as A G, the divisions of which arc decreases as it rises in such a manner as to exhibit, by the movement of A, equal portions of force acting upon E. There is however a case of common occurrence, namely, that of drawing a nail with *the fang* of a hammer, wherein the effects of the applied and resisting forces, being the hand and the nail, although acting with a lever bent at right angles, still operate as though the lever were straight; for the direction of the forces being changed to the exact amount of the same angle as that to which the lever is bent, they continue to act at right angles to their respective arms, which arms will consequently represent perpendiculars let fall from the fulcrum on their respective lines of direction.

The principle of the bent lever is not unfrequently introduced into machinery in order to gain a greater degree of power. Suppose A B C, fig. 14, to represent a bent lever moving on its fulcrum B, the operating force at A acting in the direction of A D, and the resistance at C in the direction C E: now, as the line of direction of the force C falls upon the fulcrum, it is evident, that no perpendicular can be let fall from the fulcrum upon it, and consequently, the power of C can be nothing in comparison to that of A, whose perpendicular upon its line of direction is B A; for the instant the lever begins to move, suppose to A 1, C 1, then the perpendicular on the line of direction of the force C, assumes a mensurable form, as B, B 1, whilst the power of A has only decreased from B A to B F. From this it will be seen that at the commencement of the action of A, its power over C was indefinite, but instantly after the commencement of that action by the movement of C out of the perpendicular E B, resistance likewise commenced, as the perpendicular from the fulcrum then assumed a mensurable amount.

THE WHEEL AND AXLE.

The next simple machine classed as a mechanical power, is termed the *wheel* and *axle*, and is represented at fig. 15. A the wheel, B a circular bar called the axle, both turning upon one centre, at C. In general, the force is applied by fixing a rope to the outer rim of the wheel, as represented by D, whilst the resistance, or the weight, or force to be overcome, is represented by E, attached by a rope to the axle. By a simple analysis, this machine will be found to be merely a method of obtaining a continual action of levers of the first class; for if we suppose the radius of the wheel to be the longer arm of the lever, the radius of the axle the shorter arm, and the centre on which they turn the fulcrum, we have a lever of the first class; but from these two members being circular, their radii are an indefinite number of levers, and, by the revolving of the wheel, a number of levers of this class are continually brought into operation. The effective power of the wheel and axle must therefore be calculated by the same mode as a lever of the first class; for as the radius of the wheel exceeds that of the axle, so increases the power, and so increases the distance that the operative force has to pass through.

The wheel and axle is applied in the apparatus for raising water from wells, and is introduced in many machines, which shall be shown as we proceed.

THE PULLEY.

The *pulley*, represented at fig. 16, is the third mechanic power. It is of a circular form, fixed upon a pin that runs through its centre at C, and round which it revolves. The mode of applying the pulley is by placing a rope over its outer rim, to the extremities of which, at A and B, the force to be applied, and the weight or resistance to be overcome, are indiscriminately attached, the centre C being supported by the strap D. The operations of this instrument are referable also to the action of a lever of the first class; the pin on which it revolves is the fulcrum, and the radii of the circle E F the two arms, which, being equal, no augmentation or diminution of power can arise.

When used in this manner, the pulley is but a method of altering the direction of the applied force. But if inverted, as shown in fig. 17, where the end of the line A is attached to a fixed point, the weight or resistance being at C, and the applied force acting upwards, the line from A being permanently fixed, it will become a fulcrum; and the horizontal radii of the circle assume the position of that of a lever of the second class; which gains in power as the respective forces of application and resistance are distant from the fulcrum; as B, for instance, is twice as far from A as C, the weight or force applied at B will raise twice its weight at C.

The combined action of several pullies is called a tackle, see fig. 18, where A and B are two pullies fixed in the position represented, and C D two others, capable of being either raised or lowered; the rope E passes over A, under D, over B, and under C, and is permanently fixed at F. It is therefore apparent that if the weight G be suspended from the centres of C and D, (both of which are in the position described at fig. 17,) that each of them will divide its force by two, and that one quarter of the weight G, placed at E, will counterbalance G. The pullies A and B being used only to change the direction of the action.

The construction of tackles, consisting of four pullies, or, as they are sometimes called, sheeves, is very similar to that represented by fig. 19.

For a rule to estimate the force which is necessary to overcome any force acting at G, take half the force at G and divide it by the number of lower pullies in the tackle, and it will give the amount necessary to connterbalance it at E.

THE INCLINED PLANE.

The *inclined plane* is the fourth mechanical power. It is represented at fig. 20, where A B is supposed to be a plain surface, supported at one end, so that it may lay obliquely to the horizon. By this power a heavy weight can be raised with much less force than would be required to elevate it perpendicularly. The manner of using it for the raising of weights, is, to cause the applied force to act in a direction parallel to the plane A B, and in the direction from A to B, as represented by the line A E acting on the body E; the power gained is in proportion to the length of the line A C, which is the base, compared to the perpendicular C B: now if A C be twenty feet, and C B five, then A C being four times C B, the power gained will be as four to one, that is, the force equal to the raising of one pound perpendicularly, will raise four pounds along the inclined plane A B, which being four times the length of C B, the force will have to move through four times the distance, as was shown to be the case in the use of the lever. This mechanical construction, then, offers but another mode of affecting, by the application of a small force for a longer period of time, that which would otherwise require a much more considerable force to accomplish it. The power gained in an inclined plane may be always estimated by dividing the length of the base of the plane by the perpendicular height of its most elevated end. The application of the simple inclined plane, in mechanical combinations, is not very frequent in respect to its power; but its introduction is by no means uncommon for the purpose of obtaining a regularly ascending motion. The gradual ascent of roads and railways to gain the summits of hills, and the slide-ladder used by brewers in loading and unloading their carts, are well known applications of its principle.

MECHANICAL POWERS

From 18 to 35

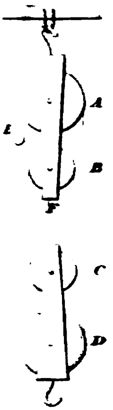


Fig. 18. p. 11.

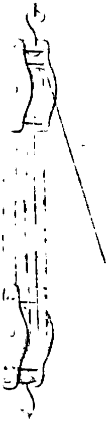


Fig. 19. p. 12.

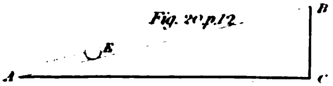


Fig. 20. p. 12.

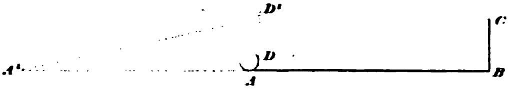


Fig. 21. p. 13.

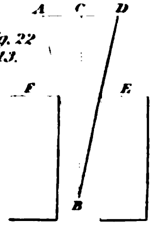


Fig. 22 p. 13.

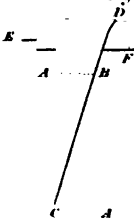


Fig. 23. p. 13.

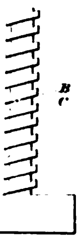


Fig. 24 p. 14

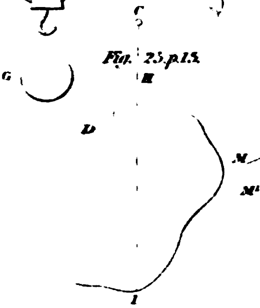


Fig. 25. p. 15.

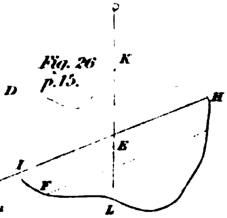


Fig. 26 p. 15.

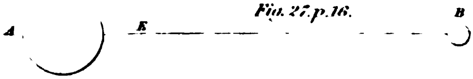


Fig. 27. p. 16.

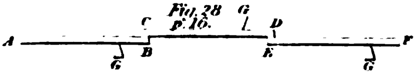


Fig. 28 p. 16.

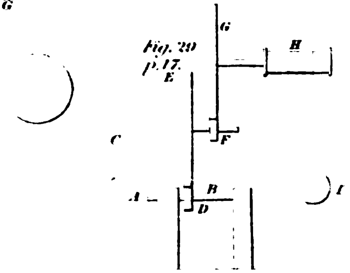


Fig. 29 p. 17.

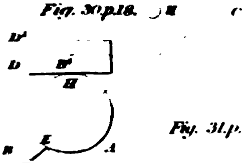


Fig. 30. p. 18.

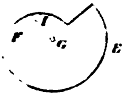


Fig. 31. p. 19.

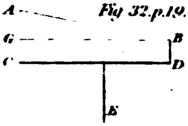
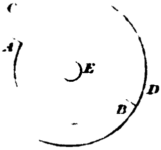


Fig. 32. p. 19.



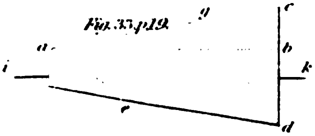


Fig. 33. p. 19.

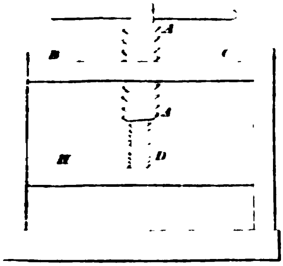


Fig. 34 p. 19.

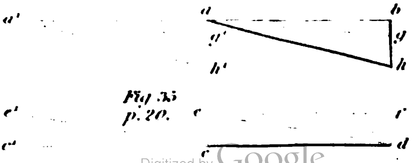


Fig. 35 p. 20.

THE WEDGE.

The fifth mechanical power is the *wedge;* one form of which is shown at fig. 21. It operates in a similar manner to the inclined plane; but instead of the resistance or force to be overcome being moved along its surface, the plane itself, which is now called the wedge, is forced beneath the object to be raised. Thus, if the wedge A B move upon a level plane to the position A 1, the weight D will be raised from its position to the height D 1; and, consequently, will pass over the whole upper plane of the wedge A B, and ultimately attain the perpendicular height B C. If A B be divided by B C, the quotient, as in the inclined plane, will represent the power which the wedge is capable of exerting; or if A B is four times B C, the power forcing forward the wedge to A 1 is capable of raising the body D four times its own amount to the position D 1. The wedge represented in fig. 22 is most generally applied to the purpose of dividing wood, where the resisting force to be overcome acts on both sides of it. To estimate the amount of power gained by this form of the instrument, we must consider it as two inclined planes, A B C and C B D conjoined; and as the forces operating at E and F are equal, we shall have, as A C is to C B, so is the resistance F to the force necessary to overcome it; and as the force E and the other portion of the wedge are similarly opposed, the total A D is to C B, as the total resistance F and E is to the power necessary to be exerted to counterbalance that resistance; or, as many times as A D will go into C B, so many times may the resistance contain the amount of the applied force.

THE SCREW.

The *screw* is the sixth and last of the mechanical powers. In the manner of its construction it is in general said to bear reference to an inclined plane wound about a cylinder; but as the power of the inclined plane corresponds with that of the wedge, and the mode of applying the facilities they possess alone forms their difference, and as the screw is almost universally moved to effect the same purposes as the wedge, it would, with greater propriety, as regards its action, bear reference to that instrument.

Fig. 23 represents a cylinder E E, upon which we will suppose the wedge-shaped piece, A B C, is capable of being wound; when wrapped round such cylinder, it will, by its upper edge B C, represent spiral lines, similar to B D and F G. Now, as the piece A B C is in the shape of a wedge or inclined plane, it should have its power estimated by the line A C compared to the height A B; and if the line B C, wound in its spiral direction, shall just circumscribe the cylinder, the point C will be found directly beneath B, and the distance between C and B, when thus lapped on the cylinder, will represent the line A B, on the perpendicular of the inclined plane or wedge; which, when compared with A C, now represented by the circumference of the cylinder, will give the same data from which the power of the screw, so formed, should be calculated. Consequently the comparison of the circumference of the screw, and the distance between one thread and another, measured on a line parallel to the axis of the screw, is that from which its power should be calculated, or as the distance between the two threads is to the circumference, so the power to be applied is to the resistance to be overcome; or if the circumference be three, and the power one, the force equal to one shall overcome a force equal to three.

Fig. 24 represents a screw of more perfect formation; but the general construction of the screw is so familiar to every one, that we conceive it to be almost needless to enter upon a more minute description. A B represents the acclivity of the plane from which such screw is formed, and the distance between B and C represents what should be compared to the circumference in order to discover the power it possesses.

The screw is applied to mechanical purposes chiefly to obtain great pressures in small distances; and upon examination it will be seen, that they afford the method of using a wedge of an extremely small inclination, and by consequence of great power. The screw is sometimes used for raising exceedingly heavy weights. The hollow screw, or the counterpart in which a screw operates, when in the form of a small moveable piece, is called a nut, and the cavity is termed a female screw, the properties of which are, as respects power, exactly similar to the screw.

We have now duly considered the nature and properties of the mechanical powers when in a state of uncombined action; and shall, in the next place, previously to representing them in some of the simplest forms in which they are combined, examine into one more attribute of matter, resulting from gravity.

THE CENTRE OF GRAVITY.

The force of gravitation, as we have already shown, acts upon matter in proportion to its quantity: thus, if a line be drawn through any body in such manner that the quantity of matter multiplied into its distance from the line on one side shall equal the quantity of matter multiplied into its distance on the opposite side, and if another line be drawn passing through the body in another direction, dividing it in a similar manner, the point where those two lines meet, whether it be situated within or about the body, is the centre of gravity; and if that point or centre, supposing it within the body, be supported, the body will remain in a state of equilibrium. Suppose the body D, fig. 25, to be suspended by a line from C, then the point H, which is called the point of suspension, and at which the body is suspended in a state of rest, will be directly above the centre of gravity. For if the perpendicular line H I be drawn, and the quantity of matter multiplied into the distance on one side of the line be not equal to the quantity of matter multiplied into the distance on the other side, the body will not be at rest; but as the body is at rest, the quantity of matter multiplied into its distance on the one side, is exactly equal to the quantity of matter multiplied into its distance on the other. Again, suspend the body as at fig. 26, and let a perpendicular fall similarly from K, the point of suspension, to L, the body will be again divided in like manner, and the point E, where the perpendicular K L intercepts the line H I, will be the centre of gravity.

If any force acting in a direct line pass through the centre of gravity of a body, it will produce uniform motion in that body; but if the force so impressed do not pass through the centre of gravity, that motion will be unequally communicated. Thus, if at fig. 26, M I represent a force striking the irregularly shaped body D, in a line of direction passing through its centre of gravity E, the force so impressed on that body will cause it to proceed with a uniform velocity, as regards all its parts; but should the force M I be impressed at the point F, as M 1, the line of direction not being through the centre of gravity, an irregular motion will be communicated, and the body will acquire a revolving motion round its centre of gravity.

As the centre of gravity is the most advantageous point for giving to a body uniform motion, so also it is the best to apply resistance to arrest the progress of that motion.

Most writers on Mechanics speak of the common centre of gravity as of more than one body, or as a system of bodies; but as they mean that those bodies should be conjoined, or their relative position maintained by some force, they may properly be considered as but one body, and the centre of gravity of the whole assemblage may be estimated in a similar manner to that of one. Thus, if the bodies A and B, fig. 27, be conjoined by a line, their common centre of gravity will be the point E; for if a line be drawn through that point in any direction, the masses of matter, multiplied into their respective distances on each side, will equal each other.

What has been said concerning the centre of gravity, is also applicable to practical points; as no body can be supported in a state of equilibrium, if the point of suspension be not exactly above or beneath its centre of gravity.

SIMPLE COMBINATIONS OF THE MECHANICAL POWERS.

Having considered the capacities of the mechanical powers, and the modes used for calculating their effects, we will now turn our attention to them in a state of combination; and as all of these instruments are in themselves gainers of power, power must be considerably increased when they become adjuncts to each other. Thus, in fig. 28, we have a combination of three levers, each of them, by the disproportion of their arms, gainers of power as three to one; G G G being their several fulcrums, the weight H will operate with thrice its power at B, by means of the lever A B; the effect will be again trebled by C D; and that amount again trebled by the action of the lever E F. Consequently, if we call H one, by A B it will be raised to three, by C D to nine, and by E F to twenty-seven; so that a weight of one pound at A will support twenty-seven pounds at F.

The combination of the action of levers may thus be extended to the gain of almost any amount of power; and when bent levers are introduced, their powers, which in peculiar situations have been shown to be very great, may in like manner be multiplied.

The wheel and axle is an implement not frequently used in its simple state. In machinery, wheels are mostly turned by means of prominences upon their peripheres called cogs, or teeth, which being acted upon by any applied force, cause the wheel to revolve; and the axle being similarly furnished with teeth, or cogs, is termed a pinion. The wheel and pinion, therefore, bear a similar relationship to each other as the wheel and axle, and their power must be calculated in the same manner. Suppose A B, fig. 29, to be a shaft on which the handle A C, of twelve inches radius, and the pinion D, of one inch radius, are fixed; and the teeth of the wheel E, of twelve inches radius, acting in those of the pinion D, and upon the shaft of E is fixed the pinion F, of one inch radius, communicating with the wheel G, of twelve inches radius, upon the shaft of which the pulley H, of one inch radius, is fastened; we shall then have the handle A C representing the radius of a wheel, and the pinion D in the situation of the axle; so that there will be a gain of twelve to one: and the wheel E, bearing the same proportion to the pinion F, will also gain in a similar ratio, and G being to H, as E to F, the gain will again be augmented to the same extent; so a force equal to one at C will operate as twelve at D; and twelve at D will operate as a hundred and forty-four at F; and at H as seventeen hundred and twenty-eight. Thus one pound at C will raise seventeen hundred and twenty-eight pounds at H, and the handle C will have to pass through seventeen hundred and twenty-eight times the distance through which the weight I will move. By this form and disposition of wheels and pinions, an accession of power is obtained; but if velocity be required at the expense of power, this train should be inverted. For, if we suppose the pulley H to be turned by a force, so as to cause the weight I to pass through one foot, the periphery of the wheel G will have passed through twelve feet, and the periphery of the pinion will have gone through the same distance; but the wheel E being twelve times the diameter of F, it will have passed through twelve times that distance, or a hundred and forty-four feet; and the pinion D, in like manner, will cause C to pass through twelve times that amount of space, or seventeen hundred and twenty eight feet; whilst the force required at H to cause this motion, must be seventeen hundred and twenty-eight times the resistance at C.

As the circumferences of wheels are proportionate to the circumferences of the pinions they have to act upon, or be acted upon by, so must the number of teeth in the one be to those in the other, otherwise the size of the teeth would not be similar; thus a wheel that is twelve inches diameter, and a pinion one inch, the circumferences of circles being in proportion to their diameters, the wheel should have twelve times as many teeth as the pinion, therefore, in practice, the number of teeth may be taken as data to estimate the power or velocity. Suppose a pinion has five teeth, and a wheel sixty, their power will be as twelve to one, as five will go twelve times in sixty; that is, the pinion will have to turn twelve times to move the wheel once; and if turned by a handle A C, whose radius is equal to the wheel, the power gained will be in the same ratio; and if the pinion is driven by the wheel, the velocity obtained will, in like manner, increase; consequently the velocities, or powers of any combination of wheels, may be estimated by their diameters, circumferences, or number of teeth.

Although this mode of communicating motion is used to a very great extent in applying wheel-work to machinery, yet, in peculiar cases, straps, chains, and cordage, of various descriptions, are beneficially introduced to transfer the action of wheels.

Combinations of the wedge are not very common: but its properties are introduced under several modifications, and afford methods of obtaining power of considerable pressure in short distances. For instance, that common and well-known part of mechanical construction, called the camb, or eccentric, is a wedge applied by one of its faces to a cylinder, which, by being turned by means of a lever, is capable of producing a powerful action. Fig. 30 represents a cylinder A, with a wedge B wound round it, but which, in this position, is denominated a camb or eccentric piece; by the motion of the lever C to the situation C 1, the cylinder A, with the camb B, is brought into the position B 1; thereby raising the obstacle D to D 1. The power gained in this operation may be ascertained thus: as the length of the lever C from the centre of A exceeds the radius of A, so will the force applied at C be increased, at the point E, where it may be supposed to act, against the wedge or camb B; and the effort to raise D may be known by considering the proportion of E F to E H, which is the portion of the circumference that must be considered as its base. Thus, if we call the length of the lever C three, and the radius of A one, if the force acting at C be one, its power at E will be three; and should the height E F be one-third of the base of the camb B, this power will be again raised by three; thus, 1 at C will counterbalance 9 at D. This movement is extremely common in order to obtain power, or a regular direct motion. It is quicker than a screw, and capable of considerable accuracy.

Fig. 31 is another modification of the wedge, placed on the internal face of the circle E, acting with its face F, and causing by its movement the obstacle I to approach nearer to the centre G; this is called the snail movement, and might with propriety be termed a concentric.

Another method of placing a wedge, so as to apply its effects to a revolving motion, is represented in a side and top view at fig. 32, where the wedge A B is placed upon a circular plate C D, turning upon the axis E, and consequently creating motion in the obstacle upon which it acts to the amount of the line G A.

Another movement of considerable accuracy is obtained by the turning of a cone, the principle of whose action is referable to the wedge. Fig. 33 represents a cone fixed upon its axis *i k*. If an obstacle be presented at *a*, and the cone be caused to pass forward in the direction *k i*, the surface *a c* will operate as a wedge at *a b c*, raising the obstacle to *c*; but if during that direct motion the cone is likewise caused to revolve on its axis, the obstacle, instead of passing over *a c*, will pass over the spiral line *a e g d*, to the point *d*; by this means the operation of a wedge, whose line of inclination is equal to the spiral line *a e g d*, and whose height is equal to *b c*, is brought into action; and if the number of revolutions of the cone be increased during its direct motion, it is plain that the effect of a wedge of infinite elongation may be produced.

The screw is introduced both singly and in a state of combination in many parts of machinery. The combined action of two screws, which avoid the necessity of using a screw of greater fineness, in which the threads would be weakened, is represented at fig. 34, where they are applied to a press. Suppose A A to be a screw fitted in a female screw in the rail B C; and D, a screw that works in the inside of A, having its lower end joined to the upper board of the press H, so that it shall not turn round: now if the screw A A, and the screw D, contain exactly the same number of threads in the inch, by turning A A one revolution, it will proceed downwards exactly the same amount that the screw D will, by the same action, proceed upwards, and the board H will not be moved. But we will suppose that the screw A A contains four threads in the inch, and the screw D six, then, by one revolution, A A will move downwards one quarter of an inch, and D will at the same time, and by the same action, be raised one-sixth of an inch, therefore the board H will move downwards the difference between one-quarter and one-sixth, or one-twelfth part of an inch, by every single revolution: which effect is similar to that which would be produced by using a screw of twelve threads to the inch.

For further elucidation we shall refer the action of each screw to that of a wedge from which the screw has been shown to be derived. Fig 35 represents two wedges, $a\ b\ h$ and $e\ c\ d$, each of which may be supposed to represent one lap of a screw of the respective fineness which their heights $b\ h$ and $e\ c$ denote. If the wedge $a\ b\ h$ be caused to pass to the situation $a^1\ a\ h^1$, and is supposed to operate upon the level surface $e\ f$, the line $a\ e$ will be compressed to the line $h^1\ c$, by that movement; but if, whilst this action takes place, the wedge $e\ c\ d$ be moved to the position $e^1\ c^1\ c$, and the effect takes place upon its upper surface $e\ d$, the line $a\ e$ will only be reduced to the line $g^1\ e$, equal to $h\ d$, and will consequently only be compressed to the amount $g^1\ a$, which is in effect equal to what a wedge of the fineness of $a\ b\ g$, would have produced, whose height or line $g\ b$ is just equal to the difference between $e\ c$ and $h\ b$, as was the case with the screws.

As a gain of power is attainable by two screws or wedges of unequal fineness, performing equal numbers of revolutions, so is the same effect attainable by the unequal revolutions of two screws or wedges of equal fineness.

Practical Application of the Mechanical Powers.

MILL GEERING.

UNDER this head we purpose to treat of the best formation of the teeth of wheels, of the connection of shafts, termed couplings, of disengaging and re-engaging of the moving parts, and of the equalization of motion; and to them we shall annex some further observations upon the general construction of Machinery. To avoid unnecessary repetition, we shall, previously to entering upon the formation of the teeth of wheels, give a general definition of the terms most commonly in use.

Cog-wheel is the general name of any wheel which has a number of teeth or cogs placed round its circumference.

Pinion is a small cog-wheel that has not in general more than twelve teeth; though, when two-toothed wheels act upon one another, the smallest is not unfrequently distinguished by this term; as is also the trundle, lantern, or wallower, when talking of the action of two wheels.

Trundle, *lantern*, or *wallower*, is sometimes used in lieu of a pinion. It is represented at fig. 36.

When the teeth of a wheel are made of the same material, and formed of one piece with the body of the wheel, they are called *teeth;* when of wood, or some other material, and affixed to the outer rim of the wheel, *cogs;* in a pinion they are called *leaves;* in a trundle *staves.*

When speaking of the action of wheel-work in general, the wheel which acts as a mover is called the *leader*, and the one upon which it acts the *follower.*

If a wheel and pinion are to be so constructed that the one shall give, and the other receive, impulse, so that the pinion shall perform four revolutions in the time that the wheel is performing one, they must be represented by two circles, which are in proportion to each other as four is to one. When these two circles are so placed that their outer rims shall touch each other, a line drawn from the centre of the one to the centre of the other is termed the *line of centres;* and the radii of the two circles the *proportional radii.* These circles are sometimes called *proportional circles*, but by millwrights in general *pitch lines.*

The teeth which are to communicate motion must be formed upon these two circles. The distance from the centres of two circles to the extremities of their respective teeth, is called the *real radii;* and, in practice, the distance between the centres of two contiguous teeth, that is, the distance from the centres of two teeth measured upon their pitch line, is called the *pitch of the wheel.* The straight part of a tooth which receives the impulse is called the *flank*, and the curved part that imparts the impulse, the *face.*

Two wheels acting upon one another in the same plane, having their axes parallel to each other, are called *spur geer;* when their axes are at right, or other angles, *bevelled geer.*

TO DESCRIBE THE CYCLOID AND EPICYCLOID.

Fig. 37. If the circle 1, having a point *a* marked on its circumference, moves along the straight line A C, and at the same time revolves on its axis, the curved line which the point *a* describes is called the cycloid. The point *a* in circle 1 is at its starting place, at B it has reached its greatest height, and at C its lowest depth; and the curved line A B C described by that point, is the *cycloid.*

Fig. 38. If the circle 1 rolls on another circle, as on the circumference of circle 2, the point *a* describes, in a similar manner to the preceding, the curve *a g h d e*, and the circles 3, 4, 5, 6, exhibit the point *a* in the several positions of a^1, a^2, a^3, a^4; $c\ a^1$ the portion of circle 3 being equal to $c\ a$, $c^2\ a^2$ to

c^2 *a*, c^3 a^3 to c^3 *a*, and c^4 a^4 to c^4 *a:* the line which is thus described is called an *exterior epicycloid.* But if the circle rolls within another circle, as the circle 1, fig. 39, rolls in the inside of circle 2, the line described by the point *a* is then called an *interior epicycloid.*

In fig. 38, the circle *a m n* is called the *generating circle of the epicycloid,* and that portion of the larger circle over which the generating circle rolls in one revolution the *base of the epicycloid.* In the interior epicycloid the generating circle of the epicycloid rolls within the circle of its base.

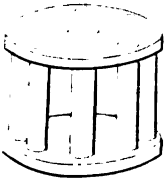
An epicycloid, either internal or external, may be conceived to be formed of numerous small portions of circles, whose radii are lines drawn from the several points of contact, as *c*, c^2, c^3, c^4, *c* being the centre of one, c^2 of another, and c^3 the centre of another, so that these lines are, as respects those several positions, radii of each circle, and perpendiculars to the epicycloid; if, therefore, a line be drawn from any point where the generating circle is in contact with the base to the point which traces the epicycloid, it will fall perpendicular to the epicycloid.

As the several lines drawn from the points of contact of the generating circle are, in all cases, the varying radii for generating the epicycloid, it is plain that when the generating circle shall have passed over half of its base, and consequently have performed half of a revolution, the diameter of the generating circle shall be a line drawn from the point of contact to the generating point, and which line shall, if prolonged, pass through the centre of the circle of the base, so that the tracing point in that part of the epicycloidal line shall be farther from, and in all other points nearer to, the base, as the perpendiculars that fall upon the epicycloid from the points of contact shall in every other position be shorter. Suppose the circle 1, fig. 40, to be a generating circle, and circle 2 to be the circle of the base, if the diameter of circle 1 be equal to the radius of circle 2, the point *a* shall trace the line *a b c* as an interior epicycloid; for if the diameter of circle 1 be equal to half of the diameter of circle 2, so will the circumference of circle 1 be equal to half of the circumference of circle 2, and consequently, when the generating circle 1 shall have performed one revolution upon the circle 2, as its base, the point *a* shall be exactly opposite to the place from where it started: now the diameter of circle 1 *is* equal to the radius of circle 2 when half way, and the tracing point is exactly in the centre of circle 2, which proves, that the epicycloid traced by the circle 1 is a straight line, and the diameter of circle 2.

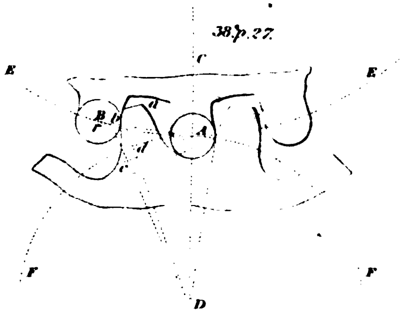
MILL GEERING

From 36 to 40.

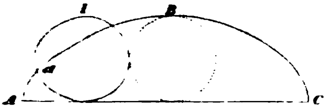
36.p.21.



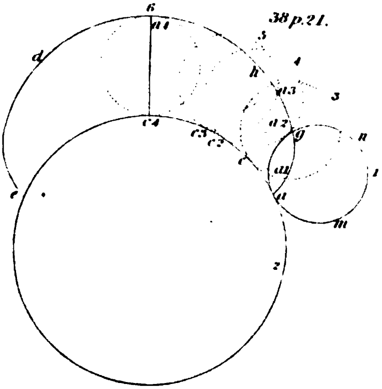
38.p.27.



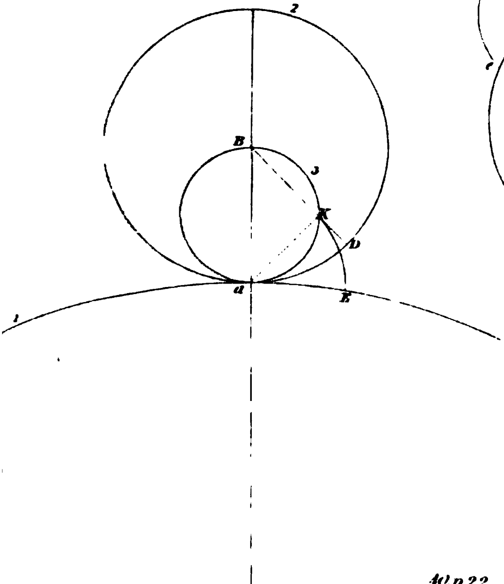
37.p.21,7.



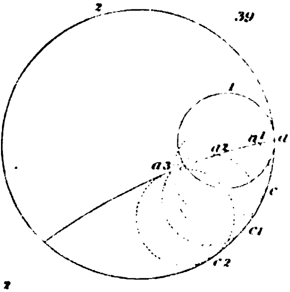
38.p.21.



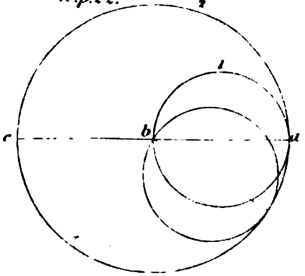
39.p.23.



39



40.p.22.



ON THE TEETH OF WHEELS.

If two cylinders be placed in close contact, motion cannot be communicated to the one without that motion, by means of the irregularities of their surfaces, (of which we have spoken under the article *Friction*,) being communicated to the other, and the smaller cylinder shall perform exactly as many revolutions to one revolution of the larger cylinder, as the larger cylinder contains upon its circumference so many measured circumferences of the smaller cylinder.

Wheels, however, which act by their surfaces only, are ill calculated to transmit motion to any considerable extent, as the motion which the follower has acquired is not of sufficient power to overcome the great resistance which would, in such case, be opposed to it; consequently it becomes necessary to have projections or teeth, and that form of the teeth will be the best which causes the wheel to act as though the motion were communicated by contact of the pitch lines.

Spur geer, fig. 39*. If the three circles 1, 2, 3, in contact at the point *a*, be made to revolve about their centres, so that they shall continually touch at the point *a*, their motions will be similar to what would have been generated by one communicating motion to the other two by contact; and circle 3 will move as though rolling on the external surface of circle 1, and internal surface of circle 2, and consequently become the generating circle of the exterior epicycloid on circle 1, and the generating circle of the interior epicycloid on circle 2. As the diameter of circle 3 is equal to the radius of circle 2, the interior epicycloid will be a straight line passing through B the centre of circle 2; and, supposing the point *a* to have performed that portion of a revolution which places it at K, a portion of the exterior epicycloid will be represented by the line E K, and a portion of the interior epicycloid by D K. Therefore, as the epicycloids D K and E K are both generated by one motion of the same point on the same circle, they will continually touch at the generating point, and the total surface of E K will pass over the total surface of D K; and if the epicycloid E K be affixed to the external surface of circle 1, and act upon the portion of the epicycloid D K, it will transmit motion to circle 2, as though that motion were communicated by contact of the pitch lines; which proves that E K presents us with the best form of tooth, and which tooth would, when acting upon the radii of the wheel to be driven, move it as though the motion were communicated by contact.

Fig. 40* represents a mode of forming the teeth of wheels when they are to act upon a trundle. Circle 1 represents the pitch line of the wheel; and circle 2 the pitch line of the trundle; which are supposed to act by contact at the point *a*. When *a* arrives at a^1, it will have traced that portion of an epicycloid represented by a^1 a^2, and as *a* is the generating point of the epicycloid, the distance from *a* to a^1, and from *a* to a^2, will be equal: and the epicycloid a^1 a^2, being generated by the proportional circle or pitch line of the trundle, presents us with the properest form for the tooth of a wheel that is to drive a trundle with circular staves posited in its pitch line.

We shall now proceed to the practical mode of applying these rules. Let circle 2 be the proportional circle or pitch line of a trundle; and circle 1 the pitch line of a wheel which is to drive that trundle: and by the revolutions of these two circles let the portion of an epicycloid a^1 a^3 be generated, so that when a line is drawn from a^3 to the centre of circle 1, it will intersect that circle at *b*, whose distance from a^1 is such, that when the semi-diameter of a staff of the trundle is subtracted from it, the remainder will be equal to half the intended thickness of the tooth of the wheel. Set off perpendicularly to the epicycloid inwards, the semi-diameter of one of the staves at so many points that you will be able to trace through the points thus set off, a line parallel to the epicycloid a^1 a^3, which line will be the face of the tooth of the wheel, being less than the tooth formed by the epicycloid a^1 a^3 by the semi-diameter of a staff of the trundle, indeed the diminution must be rather more, as the width *g g* must be made sufficient for the staves to clear themselves, as the whole of the epicycloidal line must act upon their surface.

Fig 41. To describe the teeth of a wheel for a tundle, by means of circular arcs, let us suppose A B to be the line of centres, C D the pitch line of the wheel, E F the pitch line of the trundle, and the centre of the staff G to be in the line of centres A B; then by placing one foot of the compasses in the centre of the staff G, we can describe the arc *m n*, which is the form of the face of a tooth sufficiently near that of an epicycloid for common purposes.

Fig. 42. To find the form for the teeth of a wheel and the leaves of a pinion which are to act together, we must set off on the pitch lines the points *m n a* and *p q r*, &c, according to the proper thickness of and distance between the teeth and leaves, and from these points draw radii, to serve as the

flanks of the teeth. The spaces must be of sufficient depth to allow for the action of the curved part of the teeth and leaves.

Then with the generating circle 1, whose diameter is equal to the proportional radius of the pinion, describe upon the extremities of the sides of each tooth, and upon the circumference of the proportional circle of the wheel as a base, the epicycloids *a b*, *b n;* and with the generating circle 2, describe upon the proportional circle of the pinion as a base, the epicycloid *q* D, which will give the required form of the teeth and leaves.

For if the projecting epicycloid *a b* push against the radius *f r* of the proportional pinion, the wheel and pinion will move with equal velocity; and a similar effect will be produced by the epicycloid *p* D being pushed by the radius *o m* of the wheel towards the line of centres.

Fig. 43. When one wheel is to conduct another, it is not necessary that the wheel to be conducted should have teeth of an epicycloidal form; and were the teeth not subject to wear by friction, there would be no occasion to extend the teeth of the conducted wheel beyond the pitch line; but such being the case, it becomes necessary to form the teeth of the conducted wheel in the manner represented in the figure by the dotted lines.

Mr Buchanan, in his "Essay on the Teeth of Wheels," objects to this mode of forming the teeth of the conducted wheel, and recommends that a trundle or wheel with cylindrical staves should be adopted, as it will be less acted upon in approaching the line of centres, and consequently have less friction than a pinion or wheel, the sides of whose teeth tend to the centre.

"This will appear," says he, "by fig. 44, which represents a staff, *a*, of a trundle, and a leaf, *b*, of a pinion, turning round on the same centre A, and a tooth adapted to each, turning on a common centre B. The thickness of each of the teeth, and the proportional circle of both wheels, are the same, and the proportional circles of the pinions are also equal, and teeth are each made of the greatest length which the intersection of the curves will admit, which turns out considerably greater in the tooth adapted to the staff. The shaded parts represent the tooth adapted to, and acting upon, the staff; and the dotted lines represent the tooth adapted to, and acting upon, the leaf. The teeth, in both cases, are represented as just at the point where they would cease to move the leaves or staves uniformly; and it appears the staff is conducted considerably further beyond the line of centres than the leaf; hence the staff will be less acted upon in approaching the line of centres."

As the trundle in common use is very weak and imperfect, Mr Buchanan conceived, that a wheel might be made, which would combine the advantages of both the pinion and trundle, and accordingly had some wheels made, which appeared to answer every expectation.

"These wheels," says he, "were made of cast iron. They were each cast of one solid mass. Fig. 46, No. 1, represents the edge view, and No. 2, a section of one of them; whereby is shown the manner in which the teeth are supported, like the staves of a trundle at each end, and like the leaves of a pinion at the roots, but so very thin there, as to run no risk of having the common fault of pinions, just now noticed. They were difficult to mould: but were they to come more into use, I have no doubt ingenious workmen would soon get over this obstacle."* "I mentioned," he continues' "in cases where the pinion had few teeth, that in the conducted, whether wheel or pinion, staves should be preferred; but it is obvious, that the method just described, of making a small trundle of cast iron, would not apply to a wheel of a great number of staves. Nor is it in that case so necessary, as the greater the number of teeth are, the longer they will be in losing their proper figure. In such cases, therefore, staves, strictly speaking, should not be used, but teeth made so as to produce the same effect —that is, having their acting parts of the figure of a staff. What is meant will be better understood by inspecting fig. 46, where the lines show the alteration necessary on the tooth A, in order to make it produce the effect of a staff; which staff is represented by the faint dots. The dotted lines on *d* represent the alteration requisite to adapt it to the staff, it being necessary, as formerly proved, to have it a different epicycloid from what is required to adapt it to a tooth whose acting part is a straight line, tending to the centre of its proportional circle."

"Teeth," says Mr Tredgold, in the second edition of Mr Buchanan's work, "seem to be very well adapted for various

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* By casting separate plates with indents to fix the teeth, and bolting them together, the pinion might be made sufficiently strong: such a method indeed is used frequently in crane-work, where it has the important advantage of preventing the wheels getting out of geer.

N.B. This note is by Mr Tredgold, editor of the second edition of Buchanan's "Practical Essays on Mill-work."

From 40 to 53.

Fig. 40* p. 24.

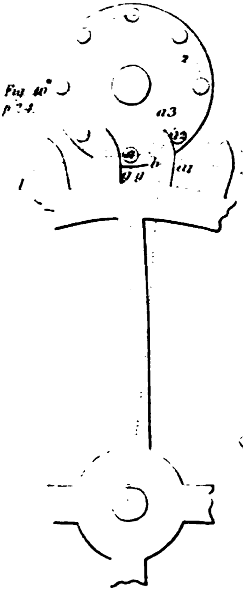


Fig. 16. p. 26.

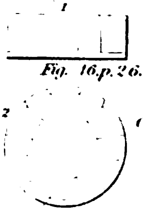


Fig. 41. p. 24.

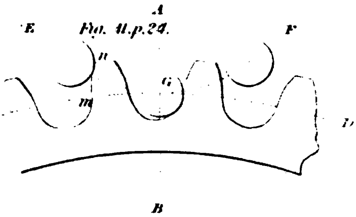


Fig. 42 p. 25.

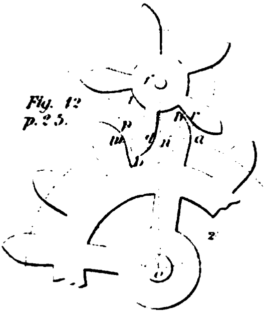


Fig. 43. p. 25.

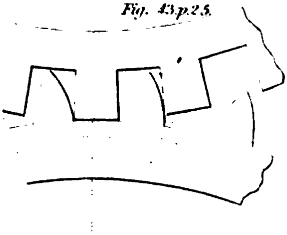


Fig. 44 p. 25.

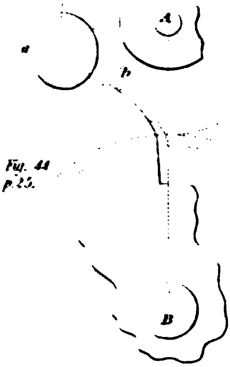


Fig. 46. p. 26.

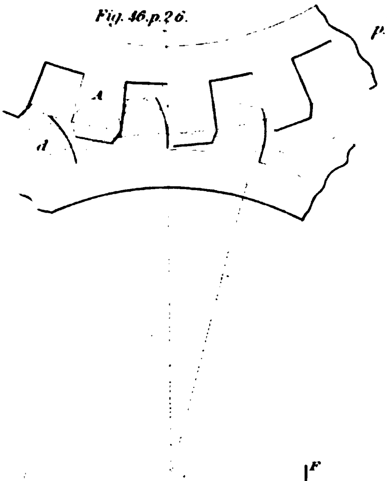


Fig. 47 p. 27.

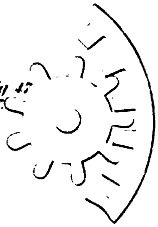


Fig. 48 p. 27.

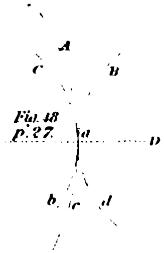


Fig. 49 p. 27.

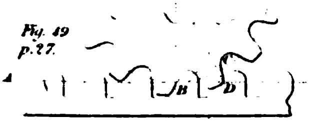


Fig. 50 p. 28

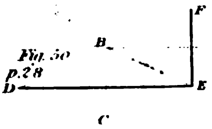


Fig. 51. p. 28.

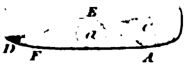


Fig. 52 p. 28.

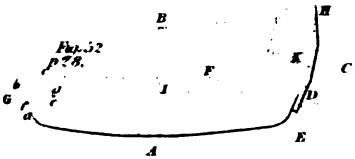
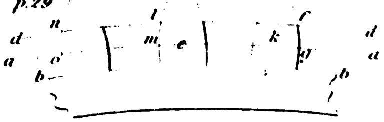


Fig. 53 p. 29



purposes, when formed on the principle recommended in the preceding article. I, therefore will endeavour to show a simple method of describing such teeth.

"It must be observed, that the teeth to resemble staves are to be always on the conducted wheel or pinion; thus affording the peculiar advantage of the wheel and trundle in either increasing or diminishing velocity.

"Fig. 38*. Let the teeth be divided as usual on the pitch lines, E E, F F; and on the conducted wheel C describe circles, as though there were to be staves. Conceive the centre of one of these staff teeth to be in the line of centres at A, and draw the line A B joining the centres of the staff teeth. Then the radius A *b*, from the centre A, will describe the curved side *b c* of the tooth of the conductor, and the curved part *b a* of the conducted wheel. And since this radius is equal to the pitch diminished by half the diameter of the circle of the staff teeth, and the centres will always be in the pitch lines of the wheels, all the other teeth may be easily described."

The editor then enters into some calculations, which the limits of our work will not permit us to pursue; we therefore refer our readers to the work itself, which embraces much useful information.

Fig. 47. When a pinion is required to have but a slow motion, an internal pinion, which has less friction than the external one, may, in many cases, be adopted with advantage.

To illustrate this, let A, fig. 48, be the proportional circle or pitch line of a wheel, B that of an external pinion, and C that of an internal pinion, all at contact at the point *a*: now, if motion be communicated to the wheels, so that they move uniformly, it will be seen, that when the point *a* has arrived at *b c d*, each of the wheels having travelled over an equal distance from the line of centres D, the space from *b* to *c* is much less than that from *c* to *d*, and consequently had the wheels moved by means of teeth, the tooth of the internal pinion C would have slid over a smaller part of a tooth of the wheel A, than a tooth of the external pinion B, which proves it would have had less velocity and less friction.

Fig. 49 represents a rack and pinion, recommended by Mr Tredgold. A B the pitch line of the rack, B C the pitch line of the pinion, and the form of the tooth C D is the involute of a circle; but when the rack impels the pinion, the curved face of each of the teeth of the rack should be a portion of a cycloid, (as A, *a*, fig. 37,) and the leaves of the pinion straight lines radiating from the centre of the pinion;

the diameter of the generating circle for describing the cycloidal teeth should be half the proportional diameter of the pinion. See *Buchanan's Practical Essays on Mill-work*. Tredgold's edition.

Bevel geer.—We have already stated, that when the axes of wheels are angular to each other, they are called bevel geer, in order to distinguish them from spur geer, whose axes are parallel; it therefore now remains for us to describe in what manner the teeth of bevel geer differ from the teeth of spur geer.

Bevel geer is represented by the two cones at fig. 50, where A B and B C are the axes, and D E and E F their proportional diameters or pitch lines.

If these two cones are placed in close contact, and motion is communicated to the one, that motion will, as is already stated, be communicated to the other, and the motion of both, as we have shown, when speaking of spur geer, will be equal.

The epicycloid for forming the teeth of bevel geer, is generated by one cone rolling upon the surface of another, while their summits coincide: for example, if a cone C, fig. 51, having a point *a*, move upon the surface of the cone D, the point *a* will, in its revolutions, describe the line A E F, A being the place from where it starts, E its greatest height, and F its lowest depth; therefore a curved line drawn from A to E, and continued from E to F, gives what is called a *spherical epicycloid;* and the base of the cone C is the *generating circle of the spherical epicycloid.* The method of using the spherical epicycloid for forming the teeth of bevel geer is, in every respect, similar to the method of using the exterior and interior epicycloid for forming the teeth of spur geer, consequently it will be needless to repeat it.

Fig. 52. To construct bevel geer we must calculate the proportional diameters or pitch lines of the wheel and pinion that are to act upon each other, and then draw their axes A B and B C. Draw parallel to the axis A B of the wheel the line D E, and the line F D parallel to the axis of the pinion, and from the point D, where these two lines intersect, draw the line D G perpendicular to A B, and D H perpendicular to B C, and make I G equal to D I, and K H equal to D K; then D G gives, what is called the *principal diameter*, or *diameter of the pitch line of the wheel*, and D H that of the pinion.

Proceed to draw the teeth of the wheel, by fixing one foot of the compasses in the point at A, and, having extended the other foot to the distance G, sweep the small arc G *a*, then set off the length of the tooth from G to *b*, draw the line *b c*, tending to *a*, and sweep the arc *c e*, concentric to *b a*. Set off from G to *f* part of the required length of the tooth, from the principal diameter to the root; and draw the line *f g* tending to A, which gives the root of the tooth. Parallel to *f g*, draw *a e*, and *a f g e* will represent a section of the solid ring of the wheel.

In an excellent article on mill-work, in Dr Rees's *Cyclopedia*, the author states, "that the manner of setting out the teeth of cog-wheels, in such a form that they shall act in the most equable manner upon each other, and with the least friction, has been a subject of much investigation among mathematicians and theoretic mechanics; but the practice and observation of the mill-wrights have produced a method of forming cog-wheels, which answers nearly, if not fully, as well in practice, as the geometrical curves which theory has pointed out to be the most proper. This they have effected by making the teeth of the modern wheels extremely small and numerous. In this case, the time of action in each pair of teeth is so small, that the form of them becomes comparatively of slight importance; and the practical methods of the mill-wrights, (using arcs of circles for the curves, approximates so nearly to the truth, that the difference is of no consequence: and this method is the best, because it so easily gives the means of forming all the cogs exactly alike, and precisely the same distance asunder, which, by the application of any other curve than the circle, is not so easy. The method, which is extremely simple, is explained in fig. 53. The wheel being made, and the cogs fixed in much larger than they are intended to be, a circle, *a a*, is described round the face of the rough cogs upon its *pitch diameter*, that is, the geometrical diameter, or acting line of the cogs; so that when the two wheels are at work together, the pitch circles, *a a*, of the two are in contact. Another circle, *b b*, is described within the pitch circle for the bottom of the teeth, and a third, *d d*, without it, for the extremities. After these preparations, the pitch circle is accurately divided into the number which the wheel is intended to have: a pair of compasses are then opened out to the extent of one and a quarter of these divisions, and with this radius arcs are struck on each side of every division, from the pitch line *a*, to the outer circle *d d*. Thus the point of the compasses being set in the divison *e*, the curve *f g*, on one side of the cog, and *n o* on one side of the other, are described; then the point of the compasses being set on the adjacent division *k*, the curve *l m* is described. This completes the curved portion of the cogs *e*, and this being done all round completes every tooth; the remaining portion of the cog within the circle *a*, is bounded by two straight lines drawn from the points *g* and *m* towards the centre; this being done to the cogs all round, the wheel is set out, and the cogs, being dressed or cut down to the lines, will be formed ready for work, every cog being of the same breadth; and the space between every one and its neighbour is exactly equal to the breadth, provided the compasses are opened to the extent of one division and a quarter as first described."

COUPLINGS.

Coupling boxes are used to connect the shafts of wheels; they are either round or square, and with single or double bearings. The square coupling with double bearings, is represented in fig. 54, where B, between the bridges C D, is a square shaft with the coupling box resting upon it, ready to be thrust, when occasion requires it, upon the shaft A, which is out of geer, and to which it can be fastened by means of a pin, as shown at F, where the shafts are in geer. The round coupling, represented in fig. 55, is, when fastened on the shafts, engaged by two bolts A B, and C, which pass through the box at right angles to each other, and one of them through each of the shafts. As it is almost impracticable to form the axes of two shafts with such accuracy that they shall present one truly straight line; and as the shafts will, though made never so accurate, wear unequally, both these couplings have been found to be somewhat disadvantageous in millwork. The square coupling with one bearing, is decidedly superior to either of the above-mentioned, as it possesses, to a certain degree, the property of being flexible in all directions. In conveying motion through a great length of shafts, where there is but little lateral pressure, it can be used to great advantage; but where there is much lateral pressure the sockets are found to wear away and get loose, which occasions a hobbling and inaccurate motion. A longitudinal section of this coupling is represented in fig. 56, where A is the square of one shaft, B the square of the other, C C the coupling box, and D D two pins, one of which passes through each square of the shafts, in order to support the square B in a line with the square A. Sometimes the square B is held in a line with the square A by means of a round projection F, from

From 54 to 69.

Fig. 54. p. 30.

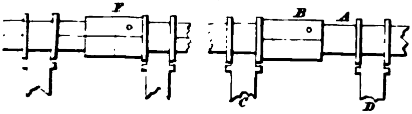


Fig. 55. p. 30.

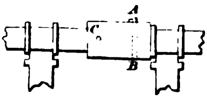


Fig. 56. p. 30.

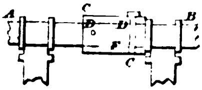


Fig. 57. p. 31.

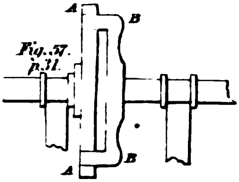


Fig. 58. p. 31.

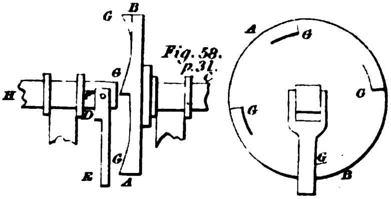


Fig. 59. p. 31.

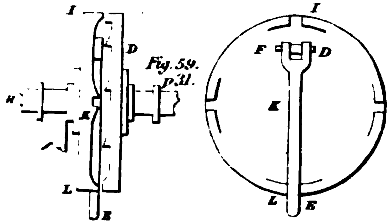
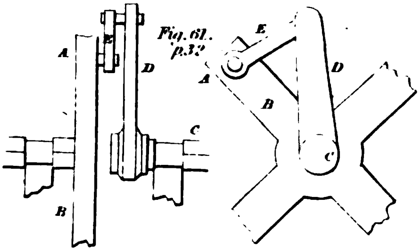


Fig. 61. p. 32.



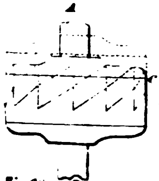


Fig. 62. p. 32.

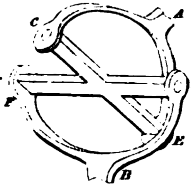
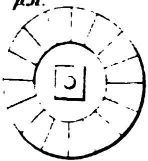


Fig. 60. p. 31.



p. 32. Fig. 63.

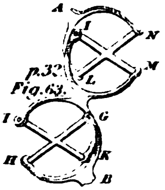


Fig. 64. p. 33.

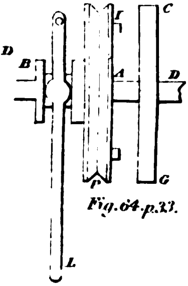
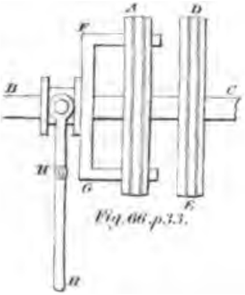


Fig. 66. p. 33.



g. 65. p. 33.

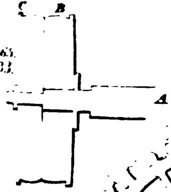


Fig. 69. p. 34.

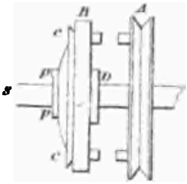


Fig. 67. p. 34.

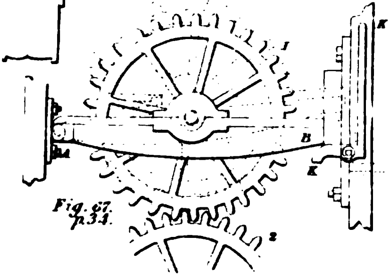
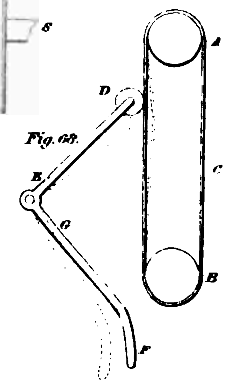


Fig. 68.



the centre of the square A, entering into a round hole in the centre of the square B.

Clutches or glands may be used with much advantage as a coupling for double bearings. Fig. 57 represents a coupling of this kind; it consists of two crosses, A A, and B B, one fixed to each shaft: B B has its ends bended forward, and lays hold of A A, which turns that shaft round.*

In boring-mills two kinds of clutches are used. The one for the smaller kinds of work is represented in fig. 58. A B is a round plate of cast iron fixed firmly on the shaft C; D E a lever fixed to the shaft H by the bolt F, and capable of being moved in the direction of the plate A B, so that it can lay hold of the projections G G G G, which will admit the boring shaft H to be thrown in and out of geer at pleasure.

The second kind of boring-mill clutch, or the one that is used to bore the largest cylinders, is represented in fig. 59. The only difference between this clutch and the one just described, consists in having the lever D E to turn on a bolt at F in a cast iron plate I K L, instead of hanging from the shaft H. Three spare sets of ears, which are cast on the plate, to be used in case of those in action breaking, support the lever near the point of pressure, and takes the stress entirely off the bolt F.

When an engine is started, it frequently happens that the crank is on the wrong side of the axis of the fly-wheel, so that both that and the shaft make one or two, and, if the attendant is negligent, several, revolutions in the wrong direction. To prevent the mischief that would accrue from such an occurrence, a coupling, as is represented in fig. 60, is introduced. A and B are two vertical shafts, maintained in the same line by a small circular pin, which passes from the shaft B into a cavity on the shaft A, which cavity is large enough to admit the pin to lay in it without communicating motion to the shaft A. The shaft B, which is connected with the moving power, has a coupling piece with prominences or teeth, perpendicular on the one side, and inclined on the other, fixed on its upper end. The coupling or catch box C, which is capable of sliding freely up and down the square part of the shaft A, has a corresponding set of teeth; by which it is evident, that when the shaft B turns the right way, the perpendicular sides of the teeth of the respective coupling pieces will act together, and carry round the upper shaft A; but when B turns in a contrary direction, the inclined sides of the teeth of the catch-box will slide over the inclined sides of the teeth of the piece on the shaft B, and cause the catch-box C to move up and down without communicating motion to the shaft A.

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* For a method of constructing glands we must refer our readers to Buchanan's *Essays on Mill-work*.

Fig. 61 represents the coupling link used by Messrs Boulton and Watt in their portable steam-engines. A, a strong iron pin, projecting from one of the arms of the fly-wheel B; D a crank connected with the shaft C; and E a link to couple the pin A and the crank D together, so that motion may be communicated to the shaft C.

Hook's universal joints are sometimes used to communicate motion obliquely instead of conical wheels. Fig. 62 represents a *single* universal joint, which may be employed where the angle does not exceed forty degrees, and when the shafts are to move with equal velocity. The shafts A and B, being both connected with a cross, move on the rounds at the points C E and D F, and thus, if the shaft A is turned round, the shaft B will likewise turn with a similar motion in its respective position.

The *double* universal joint, fig. 63, conveys motion in different directions when the angle is between 50 and 90 degrees. It is at liberty to move on the points G, H, I, K, connected with the shaft B; also on the points L, M, N, I, connected with the shaft A: thus the two shafts are so connected, that the one cannot turn without causing the other to turn likewise. These joints may be constructed by a cross of iron, or with four pins fastened at right angles upon the circumference of a hoop or of a solid ball: they are of great use in cotton mills, where the tumbling shafts are continued to a great distance from the moving power; for by applying a universal joint, the shafts may be cut into convenient lengths, and so be enabled to overcome a greater resistance.

OF DISENGAGING AND RE-ENGAGING MACHINERY.

A knowledge of the best methods of disengaging and reengaging machinery, or, as the workmen call it, throwing in and out of geer, is found to be highly necessary in most manufactories; and yet it frequently happens that the workmen are either very ignorant of, or very inattentive to, this important subject.

Matter possesses a certain property termed *inertia*, which has a tendency to maintain it in the state in which it actually is; that is to say, if a body is set in motion, this property has a tendency to maintain it for ever in that state, and certainly would, were it not gradually overcome by friction, or suddenly stopped by some stronger power; the same may be said of a body in a state of rest, as this property would ever maintain it in that state, were not some stronger force applied to set it in motion. Such being the case, it frequently occurs, when powerful machinery is moving with some velocity, and another part, which is out of geer, is suddenly connected with it, or thrown in geer, that the shock proceeding from inertia snaps the teeth of the wheels, or causes destruction to some other part of the machinery. To obviate this as much as possible, such means should be resorted to, as have been found in practice to answer best. The risk of breaking the teeth may be considerably lessened by first setting the wheel, that is to be thrown in geer, in motion by the hand.

The methods that have been adopted for throwing the machinery in and out of geer are various; some of the principal of which we shall now proceed to notice.

Fig. 64 represents the sliding pulley. P a pulley, having a hollow cylindrical bush made so that it can revolve easily upon the axle and slide backward and forward upon it; B a part of the bush projecting on one side of the pulley, having a groove sufficiently large to admit the lever L to lay in it without impeding its motion; C G a cross or gland fixed firm to the axle; and I, one or more teeth, projecting from the pulley on the side opposite to the bush. When the axle A D is required to be put in motion, the lever L must be moved towards the gross or gland C G, so that the teeth upon the pulley may catch hold of and carry it round with it.

The fast and loose pully is represented in fig. 65. B is a pulley firmly fixed on the axle A, and C a pully with a bush, so that it can revolve upon the axle A without communicating motion to it. This contrivance is remarkable for its beautiful simplicity, as the axle A can be thrown in and out of geer at pleasure, without the least shock, by simply passing a strap from the one pulley to the other.

The bayonet in its construction somewhat resembles the sliding pulley. It is shown in fig. 66. A is a pulley or binder, connected with the moving machinery by means of a strap, and revolving upon the horizontal shaft B C, which is out of geer; D E is a pulley or wheel, made of either metal or wood, fixed firmly to the horizontal shaft, and having two holes to allow the legs of the bayonet to pass through; F G is the bayonet, having a bush, and capable of being moved backward and forward upon the horizontal shaft by pushing the handle H H; so that when the shaft B C is required to be put in motion, the attendant has only to push the bayonet into the pulley D E, which will immediately carry it round.

Fig. 67 represents one of the simplest ways of disengaging and re-engaging wheels. A B, the bridge of the wheel, No. 1, acts as a lever, having its fulcrum at A; the other end of the bridge B is capable of being lifted by the key K K. When the wheel, No. 2, is required to be thrown out of geer, the key K K is pressed downwards, and the end of the bridge B rests upon the extreme end of the key, as shown by the dotted lines.

The tightening roller is represented in fig. 68. A and B are two pullies, the one to receive, and the other to transmit, motion, by means of the strap C: D is the tightening roller, fastened to a movable arm E, and connected with a lever G F. When the moving pulley, (suppose A,) is required to give motion to the other pulley B, the lever G F must be pushed downwards, which will tighten the strap by placing the tightening roller in the position represented by the dotted lines, and cause the pulley A to carry the pulley B round with it.

The friction clutch, represented in fig. 69, is used to disengage and re-engage machinery, when the velocity of the moving parts is very great. A is a pulley, having a bush, and revolving freely on the shaft S S: B is another pulley, having a similar bush, and also capable of revolving on the shaft: C C is a dish-spring, secured in its place by the pin *p p*, and forcing the pulley B against the collar D, which is fixed permanently to the shaft. When motion is required to be communicated to the shaft S S, the pulley A is moved towards the pulley B, and the teeth projecting from the side of the pulley A, clasps those of the pulley B, and carries it round with it; and the friction of the pulley B against the collar D, gradually overcomes the inertia and carries the shaft and connecting machinery also round.

The friction clutch, represented in fig. 70, is a very excellent contrivance, as it prevents all those injurious shocks which the machinery is apt to receive upon being thrown into geer. C C is a cross fixed firm on the moving shaft A; and E is a pulley or drum fixed firm on the shaft to be moved, B. When the shaft B is required to be moved, the clutch or bayonet K is made to pass through the arms of the cross, C C, and clasp the screw-hoop I I, which is by that means carried round with the shaft A, and the friction caused by the screw-hoop I I, turning upon the drum or pulley E, causes the drum and the shaft B, to which it is attached, to turn likewise.

The friction cone is very similar in its effects to the friction clutch. On the moving shaft A, fig. 71, is fixed a cone C; and on the shaft B is another cone, D, made to fit in the cone C. The cone D is movable on a square part of the shaft B, and may, by a lever, be moved in and out of geer. When the cone D is moved forward, the cone C receives motion by its internal surface.

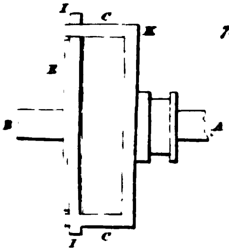
In fig. 72 is represented the self disengaging coupling. Two shafts, A and B, have each of them a cast iron wheel, with four oblique wrought iron teeth; but the wheel on the shaft is movable, on A it is fixed. When the coupling is engaged, the teeth of the wheel C lay hold of the teeth of the wheel D, and carry it, and the shaft A, round with the shaft B. E F G is a bent lever, having its fulcrum at F, which, during the ordinary stress on B, keeps forward the bayonet C, by the weight of the part F G; but when a more than usual stress comes on the shaft B, the pressure on the oblique teeth forces the bayonet back, and disengages the coupling, and the lever is held by a catch until the coupling is re-engaged by the hand of the workman.

ON EQUALIZING THE MOTION OF MACHINERY.

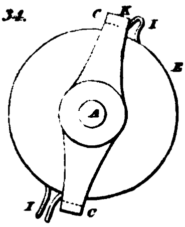
The regulation of the velocity of a mill is a matter of very great importance to preserve an uniformity of motion, either when the force of the first mover is fluctuating, or when the resistance or work of the mill varies in its degree: either or both of these causes will occasion the mill to accelerate or diminish its velocity; and in many instances it will have a very injurious effect upon the operations of the mill. Thus, in a mill for spinning cotton, wool, flax, &c. driven by a water-wheel, are a multiplicity of movements, many of which are occasionally disengaged, in different parts of the mill, for various purposes. This tends to diminish the resistance to the first mover, and the whole mill accelerates. Or, on the other hand, the head of water which drives the wheel may be liable to rise and fall suddenly, from many causes, which great and rapid rivers are subject to, and cause similar irregularities in the speed of the wheel. For such cases judicious mechanics have adopted contrivances, or regulators, which counteract all these causes of irregularity; and a large mill, so regulated, will move like a clock, with regard to its regularity of velocity. These regulators are usually called *governors*, and are made on different principles. Those most generally used are called flying-balls, operating by the centrifugal force of two heavy balls, which are connected and revolve with a vertical axis. Fig. 189, steam-engine, is the simplest form of this ingenious apparatus: A A is the vertical axis, which is constantly revolving by the machinery; at *a a* two arms or pendulums, *a b*, *a b*, are jointed, and carry at their extremities a heavy metal ball each as *b*, *b;* from the pendulum two chains or iron rods, *d d*, proceed, and suspend a collar *e*, which slides freely up and down the axis, and has a groove formed all round it, in which the end of a forked lever, D, is received; and thus the rising and the falling of the collar *e*, produces a corresponding motion of the end of the lever D; but the collar is always at liberty to turn round with the axis freely within the fork, at the extremity of the lever. The operation of the governor is this: when the vertical axis is put in motion, the centrifugal force of the balls *b*, *b*, causes them to recede from the centre; and as this is done both together, they cause the collar *e*, and the end of the lever, to rise up: the balls fly out to a certain height, and there they continue as long as the axis preserves the same velocity; as it is the property of a pendulous ball, like *b*, to make a greater effort to return to the perpendicular, in proportion as it is removed farther from it, in consequence of the suspending rod being more inclined, and bearing less of its weight. The weight of the balls to return to the axis may be considered as a constantly increasing quantity; while the quantity of the centrifugal force, causing them to recede from the axis, depends exactly upon the velocity given them. But this velocity increases as they open out, independently of any increased velocity of the axis, in consequence of their describing a larger circle. The combination of these oppositely acting forces causes the governor to be a most sensible and delicate regulator. Thus: suppose the balls hanging perpendicular put the axis in motion with a certain velocity, the centrifugal force will cause the balls to fly out; and this increasing their velocity, (by putting them farther from the centre, and causing them to revolve in a larger circle,) gives them a greater centrifugal force, which would carry them still farther from the centre, but for the counteracting force, viz. the weight of the balls tending to return. This is, as before stated, an increasing quantity, and consequently these opposite forces come to a point where they balance each other; that is, the balls fly out till their weight to return balances the centrifugal force. But if the

MILL GEERING

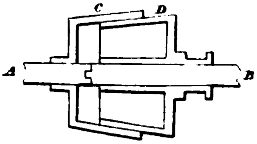
From 70 to 78.



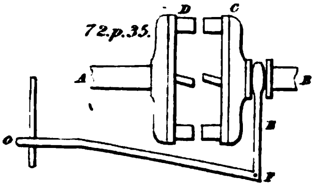
70.p.34.



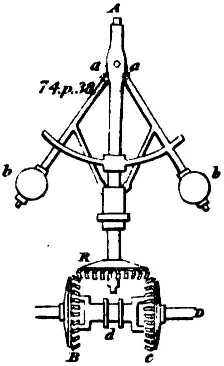
71.p.35.



72.p.35.



74.p.38.



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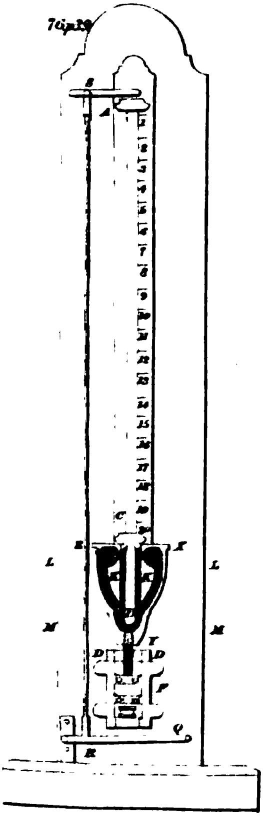
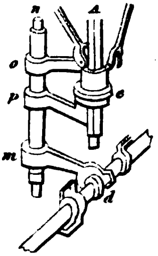
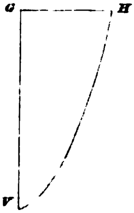


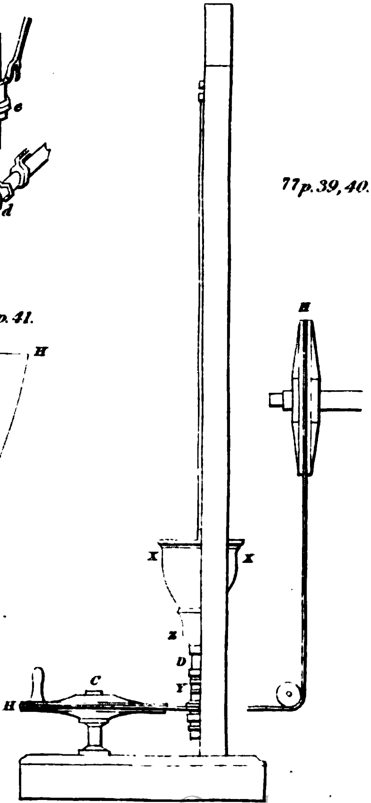
75.p.38.



78.p.41.



77.p.39,40.



slightest alteration takes place in the velocity of the axis, the equilibrium is destroyed by the increase or diminution of the centrifugal force, and the balls alter their distance from the centre accordingly, and, by elevating or depressing the end of the lever, operate upon some part of the mill to rectify the cause of the irregularity. In a steam-engine, the lever acts upon a vane or door situated in the passage of the steam from the boiler to the cylinder; and if the mill loses in velocity, from an increase of resistance, the balls fall together a little, and the consequent fall of the lever opens the door or throttle-valve a little wider, and gives a stronger supply of steam to restore the mill to its original velocity. On the other hand, if the mill accelerates, the balls open out and then close the vane, so as to moderate the supply of steam.

A water-wheel is not so easily regulated by the governor, because the shuttle of a large wheel requires a much greater force to raise or lower it, when the water is pressing against it, than the lever D, can at any time possess; it therefore becomes requisite to introduce some additional machinery, which has sufficient power to move the shuttle, and this is thrown in or out of action by the flying balls. The simplest contrivance, and that which we believe was the regulator first used for a water-wheel, was erected at a cotton-mill at Belper, in Derbyshire, belonging to Mr Strutt. A square well, or large cistern, was situated close by the water-wheel: it had a pipe leading from the mill-dam into it, to admit water; and another pipe from it to the mill-tail, to take the water away: both were closed at pleasure by cocks or sluices. Within the well was a large floating chest, very nearly filling up the space: it of course rose and fell with the water in the cistern, and had a communication by rack or wheel-work with the machinery for drawing the shuttle, so that the rise and fall of the floating chest elevated and depressed the shuttle of the wheel. The lever of the governor was connected with the cocks in the two pipes in such a manner, that when the mill was going at its intended velocity, both of the cocks were shut; but if the water-wheel went too slowly, the falling of the balls and descent of their lever D, opened the cock in the pipe of supply, and, by letting water into the well, raised the float, and, with it, the shuttle, to let more water upon the wheel, till it acquired such a velocity that the balls began to open out again, and thus shut the cock: on the other hand, if the mill went too fast, the balls opened the pipe of exit from the well, and then the sinking of the float closed the shuttle till the true velocity was restored.

Since this first application of the regulator to the water-wheel, the manner of its operation has been greatly varied; and as the same mechanism is applicable to any kind of mill-work, we shall give a slight sketch of it. Suppose A, fig. 74, an axis, receiving its motion from the mill by wheel-work; it is provided with a pair of governors, *a b*, *a b*, constructed like those before described; and at the lower part of the spindle is a bevelled wheel, R, turning two others, B and C, situated upon one spindle, D, which goes away, and communicates motion to the racks of the shuttle; the wheels, B and C, are neither of them fixed to the spindle D, but both slip round freely upon it, turning in contrary directions, as they receive motion from the opposite sides of the wheel R. A locking clutch, *d*, is fitted upon the spindle between these two wheels, B, C, and can, by moving it one way or the other, be made to lock either one of the wheels to the spindle D, at the same time that it leaves the other disengaged. The locking-box is moved by means of a lever, shown in fig. 75, the arm *m* having a fork to embrace a groove in the box; the lever is fixed on a vertical axis *n*, which has at the upper end two other levers, *o*, *p*; these lay one at each side of the vertical axis A, but at different heights, as is evident from the figure. The collar *e*, which is raised up when the balls fly out, is fitted upon a square part of the spindle A, and is formed like a snail or camm, which will act upon either of the levers *o* or *p*, according to the height at which it hangs upon its spindle. Now when the mill is going with its true velocity, this camm *e* is at such a height that it is beneath one lever, *o*, and above the other, *p*, so as to interfere with neither; consequently the locking-box, *d*, remains detached: but on any alteration in the velocity of the mill and the axis A, the balls open or shut, as before explained, and the camm, *e*, either rises or falls, and then it presses against one of the levers, *o* or *p*, and by pushing it away from the axis, it moves the lever *m*, and the locking-box *d*, up to one of the wheels, B or C, which it locks to the axis D, and turns it round in the direction of that wheel's motion, by which it either raises or depresses the water-wheel's shuttle, as is required. This apparatus may, it is plain, be applied to any other kind of mill-work.

Governors or flying-balls are very frequently used in the wind-mills employed for grinding flour: the variable force of this first mover renders some such regulator necessary, to increase the resistance, by allowing a greater feed of corn, when the mill moves too quickly, and thus in some degree counteracting the irregularity. If the mill moves too slowly, the balls tend to diminish the feed, and at the same time they raise the upper stone, to set them at a greater distance asunder, that they may require less power to drive them, and consequently suffer the mill, as nearly as it can, to retain its full velocity, though the motive force is greatly diminished. This application of the governor was, we believe, first made by the ingenious captain Hooper of Margate, who invented the horizontal wind-mill. It is a very great advantage, and no wind-mill should be without them. Many wind-mills are provided with flying-balls, which, by very ingenious mechanism, clothe and unclothe the sails just in proportion to the strength of the wind.

In many mills it is of consequence to be able to detect small variations in the velocity, and to ascertain the quantity of them; for the governor only corrects the irregularities, without showing any scale of them. In cases where this is required, it may be done by a very ingenious instrument, invented by Mr Bryan Donkin, of Fort-place, Bermondsey. He received a gold medal from the Society of Arts, Manufactures, and Commerce, in 1810, for this instrument, which he calls a tachometer.

A front view of Mr Donkin's tachometer, or instrument for indicating the velocity of Machinery, is represented in fig. 76, and a side view in fig. 77. X Y Z, fig. 76, is the vertical section of a wooden cup, made of box, which is drawn in elevation at X, fig. 77. The whiter parts of the section, in fig. 76, represent what is solid, and the dark parts what is hollow. This cup is filled with mercury up to the level L L, fig. 76. Into the mercury is immersed the lower part of the upright glass tube A B, which is filled with coloured spirits of wine, and open at both ends; so that some of the mercury in the cup enters at the lower orifice, and when every thing is at rest, supports a long column of spirits, as represented in the figure. The bottom of the cup is fastened by a screw to a short vertical spindle D, so that when the spindle is whirled round, the cup (whose figure is a solid of revolution,) revolves at the same time round its axis, which coincides with that of the spindle.

In consequence of this rotation, the mercury in the cup acquires a centrifugal force, by which its particles are thrown outwards, and that with the greater intensity, according as they are more distant from the axis, and according as the angular velocity is greater. Hence, on account of its fluidity, the mercury rises higher and higher as its recedes from the axis, and consequently sinks in the middle of the cup; this elevation at the sides and consequent depression in the middle increasing always with the velocity of rotation. Now the mercury in the tube, though it does not revolve with the cup, cannot continue higher than the mercury immediately surrounding it, nor indeed so high, on account of the superincumbent column of spirits. Thus the mercury in the tube will sink, and consequently the spirits also; but as that part of the tube which is within the cup is much wider than the part above it, the depression of the spirits will be much greater than that of the mercury, being in the same proportion in which the square of the larger diameter exceeds the square of the smaller.

Let us now suppose, that by means of a cord passing round a small pulley F, and the wheel G or H, or in any other convenient way, the spindle D is connected with the machine whose velocity is to be ascertained. In forming this connection, we must be careful to arrange matters so, that when the machine is moving at its quickest rate, the angular velocity of the cup shall not be so great as to depress the spirits below C into the wider part of the tube. We are also, as in the figure, to have a scale of inches and tenths applied to A C, the upper and narrower part of the tube, the numeration being carried downwards from zero, which is to be placed at the point to which the column of spirits rises when the cup is at rest.

Then the instrument will be adjusted, if we mark on the scale the point to which the column of spirits is depressed, when the machine is moving with the velocity required. But, as in many cases, and particularly in steam-engines, there is a continued oscillation of velocity, in those cases we have to note the two points between which the column oscillates during the most advantageous movement of the machine.

Here it is proper to observe, that the height of the column of spirits will vary with the temperature, when other circumstances are the same. On this account the scale ought to be movable, so that, by slipping it upwards or downwards, the zero may be placed at the point to which the column reaches when the cup is at rest; and thus the instrument may be adjusted to the particular temperature with the utmost facility, and with sufficient precision. The essential parts of the tachometer have now been mentioned, as well as the method of adjustment; but certain circumstances remain to be stated.

The form of the cup is adapted to render a smaller quantity of mercury sufficient than what must have been employed either with a cylindrical or hemispherical vessel. In every case two precautions are necessary to be observed:—first, that when the cup is revolving with its greatest velocity, the mercury in the middle shall not sink so low as to allow any of the spirits in the tube to escape from the lower orifice, and that the mercury, when most distant from the axis, shall not be thrown out of the cup. Secondly, that when the cup is at rest, the mercury shall raise so high above the lower end of the tube, that it may support a column of spirits of the proper length.

Now in order that the quantity of mercury, consistent with these conditions, may be reduced to its minimum, it is necessary—first, that if M M, fig. 76, is the level of the mercury at the axis, when the cup is revolving with the greatest velocity, the upper part M M X Y of the cup should be of such a form as to have the sides covered only with a thin film of the fluid; and, secondly, that for the purpose of raising the small quantity of mercury to the level L L, which may support a proper height of spirits when the cup is at rest; the cavity of the cup should be in a great measure occupied by the block K K, having a cylindrical perforation in the middle of it for the immersion of the tube, and leaving sufficient room within and around it for the mercury to move freely both along the sides of the tube and of the vessel.

The block K K is preserved in its proper position in the cup or vessel X Y Z, by means of three narrow projecting slips or ribs placed at equal distances round it, and is kept from raising or floating upon the mercury by two or three small iron or steel pins inserted into the under side of the cover, near the aperture through which the tube passes.

It would be extremely difficult, however, nor is it by any means important, to give to the cup the exact form which would reduce the quantity of mercury to its minimum; but we shall have a sufficient approximation, which may be executed with great precision, if the part of the cup above M M is made a parabolic nonoid, the vertex of the generating parabola being at that point of the axis to which the mercury sinks at its lowest depression, and the dimensions of the parabola being determined in the following manner. Let V G, fig. 78, represent the axis of the cup, and V the point to which the mercury sinks at its lowest depression; at any point G above V, draw G H perpendicular to V G; let *n* be the number of revolutions which the cup is to perform in 1″ at its quickest motion; let v be the number of inches which a body would describe uniformly in 1″, with the velocity acquired in falling from rest, through a height = to G V, and make G H $= \frac{v}{3\ 14\ n}$. Then, the parabola to be determined is that which has v for its vertex, V G for its axis, and G H for its ordinate at G. The cup has a lid to prevent the mercury from being thrown out of it, an event which would take place with a very moderate velocity of rotation, unless the sides were raised to an inconvenient height; but the lid, by obstructing the elevation at the sides of the cup, will diminish the depression in the middle, and consequently the depression of spirits in the tube: on this account a cavity is formed in the block immediately above the level L L, where the mercury stands when the cup is at rest; and thus a receptacle is given to the fluid, which would otherwise disturb the centrifugal force and impair the sensibility of the instrument.

It will be observed, that the lower orifice of the tube is turned upwards. By this means, after the tube has been filled with spirits by suction, and its upper orifice stopped with the finger, it may easily be conveyed to the cup and immersed in the quicksilver without any danger of the spirits escaping; a circumstance which otherwise it would be extremely difficult to prevent, since no part of the tube can be made capillary, consistently with that free passage to the fluids, which is essentially necessary to the operation of the instrument.

We have next to attend to the method of putting the tachometer in motion whenever we wish to examine the velocity of the machine. The pulley F, which is continually whirling during the motion of the machine, has no connection whatever with the cup, so long as the lever Q R is left to itself. But when the lever is raised, the hollow cone T, which is attached to the pulley and whirls along with it, is also raised, and embracing a solid cone on the spindle of the cup, communicates the rotation by friction. When our observation is made, we have only to allow the lever to drop by its own weight, and the two cones will be disengaged and the cup remain at rest.

The lever Q R is connected by a vertical rod to another lever S, having, at the extremity S a valve, which, when the lever Q R is raised, and the tachometer is in motion, is lifted up from the top of the tube, so as to admit the external air upon the depression of the spirits; on the other hand, when the lever Q R falls, and the cup is at rest, the valve at S closes the tube, and prevents the spirits from being wasted by evaporation.

It is lastly to be remarked, that both the sensibility and the range of the instrument may be infinitely increased; for, on the one hand, by enlarging the proportion between the diameters of the wide and narrow parts of the tube, we enlarge in a much higher proportion the extent of scale corresponding to any given variation of velocity; and on the other hand, by deepening the cup so as to admit when it is at rest a greater height of mercury above the lower end of the tube, we lengthen the column of spirits which the mercury can support, and consequently enlarge the velocity, which, with any given sensibility of the instrument, is requisite to depress the spirits to the bottom of the scale. Hence the tachometer is capable of being employed in very delicate philosophical experiments, more especially as a scale might be applied to it, indicating equal increments of velocity. But in the present account it is merely intended to state how it may be adapted to detect in machinery every deviation from the most advantageous movement.

General Observations.—In setting out the geering of a mill, it should be the object of the engineer to place the heaviest machinery nearest the moving power, as, in transmitting motion to a great distance, not only the weight of shafting is to be taken into consideration, but the friction which exists in all the different bearings, and which is greatly increased by a small obstacle placed beyond those bearings.

Care likewise should be taken to make as few bearings as possible, still keeping in view that the shafts must not be allowed to swag. Rules might be given for the distances of the bearings of the shafting, if the shafting had only to move itself, but having to carry various sized pullies, both their weight and the weight of the machinery they turn must be taken into consideration, which compel us to forego the attempt; it is, however, necessary to state, that it is better to have a bearing too many than to allow a shaft to bend, as it cannot then run true in its steps or journals.

In forming couplings, great care should be taken to make them fit, so that the coupled shaft may move as though of the same piece with the driving shaft: nor can simplicity be too strongly recommended, that the coupled shaft may, in case of an accident, be instantaneously disengaged, for the loss of time arising from any accident is of serious importance to the manufacturer. Couplings should be placed near the bearings, as there is there the least swag, and the shaft is of course the weakest at the couplings. The same observation is applicable to the disposing of wheels and pullies.

Pullies have been sometimes formed into two halves for putting upon the shaft without taking the shaft down, but their adoption is by no means general, as there is some difficulty in fixing them true whilst the shaft is in its place.

Straps to drive geering should be avoided whenever wheels can be substituted, as they are very liable to stretch and break, and do not transmit regular motion. In fixing the wheels and pullies upon a shaft, which is mostly done by driving wedges in the bush of the wheel or pully, called *staking them on*, great pains should be taken to have them true, which can only be done by driving the wedges regularly on each side to the same degree of tightness. It most generally happens when one wedge is over-driven, the workmen, rather than take the trouble to alter it, will let it remain; but this is of more importance than is generally imagined, for if a wheel is not true, it cannot work in the pitch line, all round, and where it is out it will shake, or have, what is called, *back-lash*, which, happening always in the same place, will wear the wheels irregularly. If a pulley is not true, it will communicate irregular motion by its strap, and likewise cause an irregular stress upon the shaft on which it works, much to the detriment of the bearing.

Chains have been beneficially introduced as substitutes for straps in driving heavy geer.

Shafts should be circular, as they are less likely to catch any thing, and have a much neater appearance. The same may be said of couplings. The wheels of the geering should be always enclosed in a casing of wood, called *boxing off*, to prevent any thing falling in between them, or accidents occurring to the people who may be working near them. The wheels should be furnished with brushes resting upon their faces, to distribute the grease equally, and to keep it between the teeth: and on starting a new pair of wheels, a little emery may be put on with the grease, to bring them to a smooth face.

The following general observations on the construction of Machines, and on the regulating of their motions, appear to be highly worthy of the Millwright's attention; we have, therefore, extracted them from Dr Robison's article on *Machinery*, inserted in the Supplement to the *Encyclopædia Britannica.*

When heavy stampers are to be raised, in order to drop on the matters to be pounded, the wipers by which they are lifted should be made of such a form, that the stamper may be used by a uniform pressure, or with a motion almost perfectly uniform. If this is not attended to, and the wiper is only a pin sticking out from the axis, the stamper is forced into motion at once. This occasions violent jolts to the machine, and great strains on its moving parts and their points of support; whereas, when they are gradually lifted, the inequality of desultory motion is never felt at the impelled point of the machine. We have seen pistons moved by means of a double rack on the piston rod. A half wheel takes hold of one rack, and raises it to the required height. The moment the half wheel has quitted that side of the rack, it lays hold of the other side, and forces the piston down again. This is proposed as a great improvement; connecting the unequable motion of the piston moved in the common way by a crank. But it is far inferior to the crank motion. It occasions such abrupt changes of motion, that the machine is shaken by jolts. Indeed, if the movement were actually executed, the machine would be shaken to pieces, if the parts did not give way by bending and yielding. Accordingly, we have always observed that this motion soon failed, and was changed for one that was more smooth. A judicious engineer will avoid all such sudden changes of motion, especially in any ponderous part of a machine.

When several stampers, pistons, or other reciprocal movers, are to be raised and depressed, common sense teaches us to distribute their times of action in a uniform manner, so that the machine may always be equally loaded with work. When this is done, and the observations in the preceding paragraph attended to, the machine may be made to move almost as smoothly as if there were no reciprocations in it. Nothing shows the ingenuity more than the artful yet simple and effectual contrivances for obviating those difficulties that unavoidably arise from the very nature of the work that must be performed by the machine, and of the power employed.

There is also great room for ingenuity and good choice in the management of the moving power, when it is such as cannot immediately produce the kind of motion required for effecting the purpose. We mentioned the conversion of the continued rotation of an axis into the reciprocating motion of a piston, and the improvement which was thought to have been made on the common and obvious contrivance of a crank, by substituting a double rack on the piston-rod, and the inconvenience arising from the jolts occasioned by this change. We have seen a great forge, where the engineer, in order to avoid the same inconvenience arising from the abrupt motion given to the great sledge hammer of seven hundred weight, resisting with a five fold momentum, formed the wipers into spirals, which communicated motion to the hammer almost without any jolt whatever; but the result was, that the hammer rose no higher than it had been raised in contact with the wiper, and then fell on the iron bloom with very little effect. The cause of its inefficacy was not guessed at; but it was removed, and wipers of the common form were put in place of the spirals. In this operation, the rapid motion of the hammer is absolutely necessary. It is not enough to *lift* it up; it must be *tossed* up, so as to fly higher than the wiper lifts it, and to strike with great force the strong oaken spring which is placed in its way. It compresses this spring, and is reflected by it with a considerable velocity, so as to hit the iron as if it had fallen from a great height. Had it been allowed to fly to that height, it would have fallen upon the iron with somewhat more force, (because no oaken spring is perfectly elastic,) but this would have required more than twice the time.

In employing a power which of necessity reciprocates, to drive machinery which requires a continuous motion, (as in applying the steam-engine to a cotton or grist mill,) there also occur great difficulties. The necessity of reciprocation in the first mover wastes much power; because the instrument which communicates such an enormous force must be extremely strong, and be well supported. The impelling power is wasted in imparting, and afterwards destroying, a vast quantity of motion in the working beam. The skilful engineer will attend to this, and do his utmost to procure the necessary strength of this first mover, without making it a vast load of inert matter. He will also remark, that all the strains on it, and on its supports, are changing their directions in every stroke. This requires particular attention to the manner of supporting it. If we observe the steam-engines which have been long erected, we see that they have uniformly shaken the building to pieces. This has been owing to the ignorance or inattention of the engineer in this particular. They are much more judiciously erected now, experience having taught the most ignorant that no building can withstand their desultory and opposite jolts, and that the great movements must be supported by a frame-work, independent of the building of masonry which contains it.*

The engineer will also remark, that when a single-stroke steam-engine is made to turn a mill, all the communications of motion change the direction of their pressure twice every stroke. During the working stroke of the beam, one side of the teeth of the intervening wheels is pressing the machinery forward; but during the returning stroke, the machinery, already in motion, is dragging the beam, and the wheels are acting with the other side of the teeth. This occasions a rattling at every change, and makes it proper to fashion both sides of the teeth with the same care.

It will frequently conduce to the good performance of an engine, to make the action of the resisting work unequable, accommodated to the inequalities of the impelling power. This will produce a more uniform motion in machines in which the momentum of inertia is inconsiderable. There are some beautiful specimens of this kind of adjustment in the mechanism of animal bodies.

It is very customary to add what is called a *fly* to machines. This is a heavy disk or hoop, or other mass of matter *balanced on its axis*, and so connected with the machinery as to turn briskly round with it. This may be done with the view of rendering the motion of the whole more regular, notwithstanding unavoidable inequalities of the accelerating forces, or of the resistances occasioned by the work. It becomes a *regulator*. Suppose the resistance extremely unequal, and the impelling power perfectly constant: as when a bucket-wheel is employed to *one* pump. When the piston has ended its working stroke, and while it is going down the barrel, the power of the wheel being scarcely opposed, it accelerates the whole machine, and the piston arrives at the bottom of the barrel with a considerable velocity. But in the rising again, the wheel is opposed by the column of water now pressing on the piston. This immediately retards the wheel; and when the piston has reached the top of the barrel, all the acceleration is undone, and is to begin again. The motion of such a machine is very hobbling: but the superplus of accelerating force at the beginning of a returning stroke will not make such a change in the motion of the machine if we connect the fly with it. For the accelerating momentum is a determinate quantity. Therefore, if the radius of the fly be great, this momentum will be attained by communicating a small angular motion to the machine.

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* The gudgeons of a water-wheel should never rest on the wall of the building. It shakes it; and if set up soon after the building has been erected, it prevents the mortar from taking firm bond; perhaps by shattering the calcareous crystals as they form. When the engineer is obliged to rest the gudgeons in this way, they should be supported by a block of oak laid a little hollow. This softens all tremors, like springs of a wheel carriage. This practice would be very serviceable in many other parts of the construction.

The momentum of the fly is as the square of its radius; therefore it resists acceleration in this proportion; and although the overplus of power generates the same momentum of rotation in the whole machine as before, it makes but a small addition to its velocity. If the diameter of the fly be doubled, the augmentation of rotation will be reduced to one-fourth. Thus, by giving rapid motion to a small quantity of matter, the great acceleration during the returning stroke of the piston is prevented. This acceleration continues, however, during the whole of the returning stroke, and at the end of the machine has acquired its greatest velocity. Now the working stroke begins, and the overplus of power is at an end. The machine accelerates no more; but if the power is just in equilibrio with the resistance, it keeps the velocity which it has acquired, and is still more accelerated during the *next* returning stroke. But now, at the beginning of the subsequent working stroke, there is an overplus of resistance, and a retardation begins, and continues during the whole rise of the piston; but it is inconsiderable in comparison of what it would have been without the fly; for the fly, retaining its acquired momentum, drags forward the rest of the machine, aiding the impelling power of the wheel. It does this by all the communications taking into each other in the opposite direction. The teeth of the intervening wheels are heard to drop from their former contact on one side, to a contact on the other. By considering this process with attention, we easily perceive that, in a few strokes, the overplus of power during the returning stroke comes to be so adjusted to the deficiency during the working stroke, that the accelerations and retardations exactly destroy each other, and every succeeding stroke is made with the same velocity, and an equal number of strokes is made in every succeeding minute. Thus the machine acquires a general uniformity with periodical inequalities. It is plain, that by sufficiently enlarging either the diameter or the weight of the fly, the irregularity of the motion may be rendered as small as we please. It is much better to enlarge the diameter. This preserves the friction more moderate, and the pivot wears less. For these reasons a fly is in general a considerable improvement in machinery, by equalizing many exertions that are naturally very irregular. Thus, a man working at a common windlass exerts a very irregular pressure on the winch. In one of his positions, in each turn he can exert a force of near 70 lbs. without fatigue, but in another he cannot exert above 25 lbs; nor must he be loaded with much above this in general. But if a large fly be connected properly with the windlass, he will act with equal ease and speed against 30 lbs.

This regulating power of the fly is without bounds, and may be used to render uniform a motion produced by the most desultory and irregular power. It is thus that the most regular motion is given to mills that are driven by a single stroke steam-engine, where, for two, or even three seconds, there is no force pressing round the mill. The communication is made through a massive fly of very great diameter, whirling with great rapidity. As soon as the impulse ceases, the fly, continuing its motion, urges round the whole machinery with almost unabated speed. At this instant all the teeth, and all the joints, between the fly and the first mover, are heard to catch in the opposite direction.

If any permanent change should happen in the impelling power, or in the resistance, the fly makes no obstacle to its producing its full effect on the machine; and it will be observed to accelerate or retard uniformly, till a new general speed is acquired exactly corresponding with this new power and resistance.

Many machines include, in their construction, movements which are equivalent with this intentional regulator. A flour mill, for example, cannot be better regulated than by its mill-stone; but in the Albion Mills, a heavy fly was added with great propriety; for if the mills had been regulated by their mill-stones only, then, at every change of stroke in the steam-engine, the whole train of communications between the beam, which is the first mover, and the regulating mill-stone, which is the very last mover, would take in the opposite direction. Although each drop in the teeth and joints be but a trifle, the whole, added together, would make a considerable jolt. This is avoided by a regulator immediately adjoining the beam. This continually presses the working machinery in one direction. So judiciously were the movements of that noble machine contrived, and so nicely were they executed, that not the least noise was heard, nor the slightest tremor felt in the building.

Mr. Valoué's beautiful pile engine, employed at Westminster bridge, is another remarkable instance of the regulating power of a fly. When the ram is dropped, and its follower disengaged immediately after it, the horses would instantly tumble down, because the load, against which they had been straining hard, is at once taken off; but the gin is connected with a very large fly, which checks any remarkable acceleration, allowing the horses to lean on it during the descent of the load; after which their draught recommences immediately. The spindles, cards, and bobbins, of a cotton-mill, are also a sort of flies. Indeed, all bulky machines of the rotative kind tend to preserve their motion with some degree of steadiness, and their great momentum of inertia is as useful in this respect as it is prejudicial to the acceleration or any reciprocation when wanted. There is another kind of regulating fly, consisting of wings whirled briskly round, till the resistance of the air prevents any great acceleration. This is a very bad one for a *working* machine, for it produces its effect by *really wasting* a part of the moving powers. Frequently it employs a very great and unknown part of it, and robs the proprietor of much work. It should never be introduced into any machine employed in manufactures.

Some rare cases occur where a very different regulator is required: where a certain determined velocity is found necessary. In this case the machine is furnished, at its extreme mover, with a conical pendulum, consisting of two heavy balls hanging by rods, which move in very nice and steady joints at the top of a vertical axis. It is well known, that when this axis turns round, with an angular velocity suited to the length of those pendulums, the time of a revolution is determined. Thus, if the length of each pendulum be 39⅛ inches, the axis will make a revolution in two seconds very nearly. If we attempt to force it more swiftly round, the balls will recede a little from the axis, but it employs as long time for a revolution as before; and we cannot make it turn swifter, unless the impelling power be increased beyond all probability; in which case the pendulum will fly out from the centre till the rods are horizontal, after which every increase of power will accelerate the machine very sensibly. Watt and Boulton have applied this contrivance with great ingenuity to their steam-engines, when they are employed for driving machinery for manufactures which have a very changeable resistance, and where a certain speed cannot be much departed from without great inconvenience. They have connected this recess of the balls from the axis, (which gives immediate indication of an increase of power or a diminution of resistance,) with the cock which admits the steam to the working cylinder. The balls flying out, causes the cock to close a little, and diminish the supply of steam. The impelling power diminishes the next moment, and the balls again approach the axis, and the rotation goes on as before, although there may have occurred a very great excess or deficiency of power.

A fly is sometimes employed for a very different purpose from that of a regulator of motion—it is employed as a *collector of power*. Suppose all resistance removed from the working point of a machine furnished with a very large or heavy fly immediately connected with the working point. When a small force is applied to the impelled point of this machine, motion will begin in the machine and the fly begin to turn. Continue to press, uniformly, and the machine will accelerate. This may be continued till the fly has acquired a very rapid motion. If at this moment a resisting body be applied to the working point, it will be acted on with very great force; for the fly has now accumulated in its circumference a very great momentum. If a body were exposed immediately to the action of this circumference, it would be violently struck. Much more will it be so, if the body be exposed to the action of the working point, which, perhaps, makes one turn while the fly makes a hundred. It will exert a hundred times more force there, (very nearly,) than at its own circumference. All the motion which has been accumulated on the fly during the whole progress of its accumulation, is exerted in an instant at the working point, multiplied by the momentum depending on the proportion of the parts of the machine. It is thus that the coining press performs its office; nay, it is thus that the blacksmith forges a bar of iron. Swinging the great sledge hammer round his head, and urging it with force the whole way, this accumulated motion is at once extinguished by impact on the iron. It is thus also we drive a nail, &c. This accumulating power of a fly has occasioned many to imagine that a fly really adds power or mechanical force to an engine; and, not understanding on what its efficacy depends, they often place the fly in a situation where it only adds a useless burden to the machine. It should always be made to move with rapidity. If intended for a mere regulator, it should be near the first mover; and if it be intended to accumulate force in the working point, it should not be far separated from it. In a certain sense, a fly may be said to add power to a machine, because by accumulating into the exertion of one moment the exertions of many, we can sometimes overcome an obstacle that we never could have balanced by the same machine, unaided by the fly. And it is this accumulation of force which gives such an appearance of power to some of our first movers.

ANIMAL STRENGTH.

ANIMAL STRENGTH has been very differently estimated by different authors; but this is not to be wondered at when we consider the many difficulties that ever must attend any attempt to subject it to an estimate. Physical causes must sensibly affect the extent and duration of animal exertion, either in man or beast; and the only way of coming to any thing like an accurate result, is to compare the experiments of the different philosophers who have attended to the subject. This has been already done by Dr Young, in the second volume of his *Philosophy*, whose valuable tables we here present to our readers.

Comparative table of mechanical forces.

In order to compare the different estimates of the force of moving powers, it will be convenient to take a unit which may be considered as the mean effect of the labour of an active man, working to the greatest possible advantage, and without impediment. This will be found on a moderate estimation sufficient to raise 10 pounds, 10 feet in a second, for ten hours in a day; or to raise a 100 pounds, which is the weight of twelve wine gallons of water, one foot in a second, or 36,000 feet in a day; or 3,600,000 pounds, or 432,000 gallons, one foot in a day. This we may call a force of one continued 36,000″.

Immediate force of men, without deduction for friction.

	Force.	Continuance.	Day's work.
A man, weighing 133 pounds, Fr. ascended 62 feet, Fr. by steps, in 34″, but was completely exhausted.—Amontons	2,8	34″	
A sawyer made 200 strokes of 18 inches Fr. each, in 145″, with a force of 25 pounds, Fr. He could not have gone on above three minutes.—Amontons .	6	145	
A man can raise 60 pounds, Fr. one foot, Fr. in 1″, for eight hours a day.—Bernouilli . . .	69	8^h	,552
A man of ordinary strength can turn a winch with a force of 30 pounds, and with a velocity of 3½ feet in 1″, for 10 hours a day.—Desaguliers . .	1,05	10^h	1,05

	Force.	Continuance.	Day's work.
Two men working at a windlass with handles at right angles, can raise 70 pounds more easily than one can raise 30.—Desaguliers	1,22		1,22
A man can exert a force of 40 pounds for a whole day, with the assistance of a fly, when the motion is pretty quick, at about four or five feet in 1″.—Desaguliers, Lect. iv. But from the annotation it appears to be doubtful whether the force is 40 pounds or 20	,2		,2
For a short time a man may exert a force of 80 pounds with a fly, "when the motion is pretty quick."—Desaguliers	,3	1″	
A man going up stairs ascends 14 metres in 1′.—Coulomb	1,182	1′	
A man going up stairs for a day raises 205 chiliogrammes to the height of a chiliometre.—Coulomb			,412
With a spade a man does nineteen-twentieths as much as in ascending stairs.—Coulomb			,391
With a winch a man does five-eighths as much as in ascending stairs.—Coulomb			,258
A man carrying wood up stairs raises, together with his own weight, 109 chiliogrammes to one chiliometre.—Coulomb			,219
A man weighing 150 pounds, Fr. can ascend by stairs three feet, Fr. in 1″ for 15″ or 20″.—Coulomb	5,22	20″	
For half an hour, 100 pounds, Fr. may be raised one foot, Fr. in 1″.—Coulomb	1,152	30″	
According to Mr. Buchanan's comparison, the force exerted in turning a winch being made equal to the unit, the force in pumping will be	,61		
In ringing	1,36		
In rowing	1,43		
Allowing the accuracy of Euler's formula, confirmed by Schulze, supposing a man's action to be a maximum when he walks $2\frac{1}{2}$ miles an hour, we have $7\frac{1}{2}$ for his greatest velocity, $,04(7\frac{1}{2}-v)^2$ for the force exerted with any other velocity, and $0160(7\frac{1}{2}-v)^2$ for the action in each case; thus, when the velocity is one mile an hour, the action is	,676		
When two miles	,964		
When three	,972		
When four	,784		
And when five	,5		

And the force in a state of rest becomes $2\frac{1}{4}$, or about 70 pounds; with a velocity of two miles, 36 pounds; with three, 24 pounds; and with four, 15.

It is obvious that in the extreme cases this formula is inaccurate, but for moderate velocities it is probably a tolerable approximation.

Coulomb makes the maximum of effect when a man, weighing 70 chiliogrammes, carries a weight of 53 up stairs, but this appears to be too great a load; he considers 145 chiliogrammes as the greatest weight that can be raised. He observes that in Martinique, where the thermometer is seldom below 68°, the labour of Europeans is reduced to one-half.

Harriot asserts that his pump, with a horizontal motion, enables a man to do one-third more work than the common pump with a vertical motion.

Porters carry from 200 to 300 pounds at the rate of three miles an hour; chairmen walk four miles an hour with a load of 150 pounds each; and it is said that in Turkey there are porters who, by stooping forward, carry from 700 to 900 pounds placed very low on their backs.

The most advantageous weight for a man of common strength to carry horizontally, is 111 pounds; or if he returns unladen, 135. With wheel-barrows, men will do half as much more work as with hods.—Coulomb.

Performance of men by machines.

	Force.	Continuance.	Day's work.
A man raised by a rope and pulley 25 pounds, Fr. 220 feet, Fr. in 145″.—Amontons . . .	,436	145″	
A man can raise, by a good common pump, a hogshead of water 10 feet high in a minute, for a whole day.—Desaguliers	,875		,875
By the mercurial pump, or any other good pump, a man may raise a hogshead 18 or 20 feet in a minute, for one or two minutes	1,61	1′	
In a pile engine, 55½ pounds, Fr. were raised one foot, Fr. in 1″ for five hours a day, by a rope drawn horizontally.—Coulomb	,64	5h	,82
Robison says, that a feeble old man raised seven cubic feet of water, 11½ feet in 1′, for eight or ten hours a day, by walking backwards and forwards on a lever.—*Enc. Br.*	,837	9h	,753
A young man weighing 135 pounds, and carrying 30, raised 9¼ cubic feet, 11½ feet high, for ten hours a day, without fatigue.—Robison	1,106	10h	1,106
Wynner's machine enables a man to raise a hogshead 20 feet in a minute.—Y.	1,75	1′	

Force of horses.

	Force.	Continuance.	Day's work.
Two horses, attached to a plough on moderate ground, exerted each a force of 150, Fr.—Amontons. We may suppose that they went a little more than two miles an hour, for eight hours . . .	5,4	8h	4,32
A horse draws with the greatest advantage when the line of direction is level with his breast; and he can draw with a force of 200 pounds, 2½ miles an hour, for eight hours in the day	7,33	8h	5,87
With a force of 240 only six hours. On a carriage, indeed, where friction alone is to be overcome, a middling horse will draw 1000 pounds.—Desaguliers	8,8	6h	5,28
The mean draught of four horses was 36 myriogrammes each, or 794 pounds.—Regnier. This must have been momentary. Supposing the velocity two feet in a second, the action would have been .	15,88	1″	
By means of pumps a horse can raise 250 hogsheads of water, 10 feet high, in an hour.—Smeaton's Reports	3,64	1h	

A horse can in general draw no more up a steep hill than three men can carry; that is from 450 to 750 pounds; but a strong horse can draw 2000 pounds up a steep hill, which is but short. The worst way of applying the force of a horse, is to make him carry or draw up hill; for if the hill be steep, three men will do more than a horse, each man climbing up faster with a burden of 100 pounds' weight, than a horse that is loaded with 300 pounds: a difference which is owing to the position of the parts of the human body being better adapted to climb than those of a horse.

On the other hand, the best way of applying the force of a horse, is an horizontal direction, wherein a man can exert least force; thus a man, weighing 140 pounds, and drawing a boat along, by means of a rope coming over his shoulders, cannot draw above 27 pounds, or exert above one-seventh part of the force of a horse employed to the same purpose.

The very best and most effectual posture in a man is that of rowing; wherein he not only acts with more muscles at once for overcoming the resistance than in any other position; but as he pulls backwards, the weight of his body assists by way of lever.—Desaguliers.

The diameter of a walk for a horse-mill ought to be at least 25 or 30 feet.—Desaguliers.

Some horses have carried 650 or 700 pounds, seven or eight miles, without resting, as their ordinary work; and a horse at Stourbridge carried eleven hundred weight of iron, or 1232 pounds, for eight miles.—Desaguliers, *Experimental Philosophy*, vol. i.

Work of mules.

	Force.	Continuance.	Day's work.
Cazanel says, that a mule works in the West Indies two hours out of about 18, with a force of about 150 pounds, walking three feet in a second.—Dr Young's *Philosophy*.	4,5	$2^{h}\,40'$	1,2

These examples exhibit the great advantages which may be gained by directing the exertion of animals in a proper course, their effects being plainly reducible to the operations of mechanical powers. To describe the various modes of applying animal strength, as a first mover of mechanical engines, would greatly exceed our limits; we shall therefore merely state, that the most common machine for receiving the force of animals is the horse-walk, which affords the means of applying the action of that animal to create rotative motion. The horse walk is formed of an horizontal lever or arm, attached to an upright spindle. The lever should not be less than twelve feet, as the labour of the animal is greatly increased by a small curve, which causes an unequal resistance upon his two shoulders. The machine should be so regulated that the horse may not be required to deviate from his usual pace of two miles and a half, with a burden, an hour. The gives, in which the horse works, should not be immovably fixed to the arms, but hung by a swivel joint, so that he may place himself in the most comfortable position. The work should be supplied to the machinery as regularly as possible.

Having, in the preceding account, stated the mean results of human exertion when applied to regular and uniform labour, we shall in the next place proceed to notice some extraordinary feats of strength, as well as some that had the appearance of being such, but which were, in reality, the mere effects of contrivance and skill, and which might have been performed by almost any men who were possessed of that knowledge of their construction as would enable them similarly to exert their strength to the best advantage.

M. de la Hire, in an *Examination of the Force of Men*, (vide Memoirs of the Academy of Sciences for 1699,) says, "There are men whose spirits flow so abundantly into their muscles, that they exert three or four times more strength than others do; and this seems to be the natural reason of the surprising strength that we see in some men who carry and raise weights which two or three ordinary men can hardly sustain, though these men be sometimes but of a moderate stature, and rather appear weak than strong. There was a man in this country a little while ago, who would carry a very large anvil, and of whom was reported several wonderful feats of strength. But I saw another at Venice, who was but a lad, and did not seem able to carry above forty or fifty pounds, with all possible advantages; yet this young fellow, standing upon a table, raised from the earth, and sustained off the ground, an ass, by means of a broad girth, which, going under the creature's belly, was hung upon two hooks that were fastened to a plat of small cords coming down in tresses from the hair on each side of the lad's head, which were in no great quantity. And all this great force *depended only upon the muscles of the shoulders and those of the loins:* for he stooped at first whilst the hooks were fastened to the girth, and then raised himself, and lifted up the ass from the ground, bearing with his hands upon his knees. He raised also in the same manner other weights that seemed heavier, and used to say he did with more ease, because the ass kicked and struggled when first lifted from the ground."

Dr. Desaguliers, in some annotations upon De la Hire's paper, says, " What he attributes here *to the muscles of the loins*, were really performed by the extensors of the legs; for the young man's stooping with his hands upon his knees was not with his body forwards and his knees stiff, but his body upright and his knees bent, so as to bring the two cords with which he lifted to be in the same plane with his ancles and the heads of his thigh-bones; by which means the line of direction of the man and the whole weight came between the strongest part of his two feet, which are the supports: then as he extended his legs he raised himself, without changing the line of direction. That this must have been the manner I am pretty well assured of, by not only observing those that perform such feats, but having often tried it myself. As for the muscles of the loins, they are incapable of that strain, being above six times weaker than the extensors of the legs; at least I found them so in myself.

" About the year 1716, having the honour of showing a great many experiments to his late majesty King George I., his majesty was desirous to know whether there were any fallacy in those feats of strength that had been shown half a year before by a man, who seemed by his make to be no stronger than other men: upon this I had a frame of wood made to stand in, (and to rest my hands upon,) and with a girdle and chain lifted an iron cylinder, made use of to roll the garden, sustaining it easily when once it was up. Some noblemen and gentlemen who were present tried the experiment afterwards, and lifted the roller; some with more ease, and some with more difficulty, than I had done. This roller weighed 1,900 pounds, as the gardener told us. Afterwards I tried to lift 300 pounds with my hands, (viz. two pails with 150 pounds of quicksilver in each,) which I did indeed raise from the ground, but strained my back so as to feel it three or four days; which shows that, in the same person, the muscles of the loins, (which exerted their force in this last experiment,) are more than six times weaker than the extensors of the legs; for I felt no inconveniency from raising the iron roller."

During the time that Dr Desaguliers was occupied in printing the second volume of his *Philosophy*, a man of great natural strength exhibited himself in London, of whom the doctor gives the following account.

"Thomas Popham, born in London, and now about thirty-one years of age, five feet ten inches high, with muscles very hard and prominent, was brought up a carpenter, which trade he practised till within these six or seven years that he has showed feats of strength; but he is entirely ignorant of any art to make his strength more surprising. Nay, sometimes he does things which become more difficult by his disadvantageous situation; attempting, and often doing, what he hears other strong men have done, without making use of the same advantages.

"About six years ago he pulled against a horse, setting upon the ground with his feet against two stumps driven into the ground, but without the advantages which might have been attained by placing himself in a proper situation; the horse, however, was not able to move him, and he thought he was in the right posture for drawing against a horse; but when, in the same posture, he attempted to draw against two horses, he was pulled out of his place by being lifted up, and had one of his knees struck against the stumps, which shattered it so, that, even to this day, the *patella*, or knee-pan, is so loose, that the ligaments of it seem either to be broken or quite relaxed, which has taken away most of the strength of that leg."

Dr Desaguliers then relates the exploits which he saw him perform.

"1. By the strength of his fingers, (only rubbed in coal ashes to prevent them from slipping,) he rolled up a very strong and large pewter dish.

"2. He broke seven or eight short and strong pieces of tobacco-pipe with the force of his middle finger, having laid them on the first and third finger.

"3. Having thrust in under his garter the bowl of a strong tobacco-pipe, his legs being bent, he broke it to pieces by the tendons of his hams, without altering the bending of his knee.

"4. He broke such another bowl between his first and second finger, by pressing his fingers together sideways.

"5. He lifted a table six feet long, which had half a hundred weight hanging at the end of it, with his teeth, and held it in an horizontal position for a considerable time. It is true, the feet of the table rested against his knees; but, as the length of the table was much greater than its height, that performance required a great strength to be exerted by the muscles of his loins, those of his neck, the *masseter* and *temporal*, (muscles of the jaws,) besides a good set of teeth.

"6. He took an iron kitchen poker, about a yard long, and three inches in circumference, and, holding it in his right hand, he struck upon his bare left arm, between the elbow and the wrist, till he bent the poker nearly to a right angle.

"7. He took such another poker, and holding the ends of it in his hands, and the middle against the back of his neck, he brought both ends of it together before him; and, what was yet more difficult, he pulled it almost straight again: because the muscles which separate the arms horizontally from each other are not so strong as those that bring them together.

"8. He broke a rope of about two inches in circumference, which was in part wound about a cylinder of four inches diameter, having fastened the other end of it to straps that went over his shoulders. But he exerted more force to do this than any other of his feats, from his awkwardness in going about it; for the rope yielded and stretched as he stood upon the cylinder, so that when the extensors of the legs and thighs had done their office in bringing his legs and thighs straight, he was forced to raise his heels from their bearings, and use other muscles that are weaker. But if the rope had been so fixed that the rope to be broken had been short, it would have been broken with four times less difficulty.

"9. I have seen him lift a rolling stone of about 800 pounds with his hands only, standing in a frame above it, and taking hold of a chain that was fastened to it. By this, I reckon, he may be almost as strong again as those who are generally reckoned the strongest men, they generally lifting no more than 400 pounds in that manner. The weakest men who are in health, and not too fat, lift about 125 pounds, having about half the strength of the strongest.

"N. B. This sort of comparison is chiefly in relation to the muscles of the loins; because in doing this, one must stoop forwards a little. We must also add the weight of the body to the weight lifted. So that if the weakest man's body weighs 150 pounds, that, added to 125 pounds, makes the whole weight lifted by him to be 275 pounds. Then, if the strongest man's body weighs also 150 pounds, the whole weight lifted by him will be about 550 pounds, that is 400 pounds and the 150 pounds which his body weighs. Popham weights about 200 pounds, which, added to the 800 pounds that he lifts, makes 1000 pounds, But he ought to lift 900 pounds besides the weight of his body, to be as strong again as a man of 150 pounds weight who can lift 400 pounds.

"About thirty years ago, one *Joyce*, a Kentish man, famous for his great strength, showed several feats in London and the country, which so much surprised the spectators, that he was by most people called *the second Sampson*. But though the postures which he had learnt to put his body into, and found out by practice, without any mechanical theory, were such as would make a man of common strength do such feats as would appear surprising to every one who did not know the advantage of those positions of the body, yet nobody then attempted to draw against horses, or raise great weights, or to do any thing in imitation of him: because, as he was very strong in the arms, and grasped those that tried his strength that way so hard that they were obliged immediately to desire him to desist, his other feats, (wherein his manner of acting was chiefly owing to the mechanical advantage gained by the position of his body,) were entirely attributed to his extraordinary strength.

"But when he had been gone out of England, or had ceased to show his performance, for eight or ten years, men of ordinary strength had found out the way of making such advantage of the same postures as *Joyce* had put himself into, as to pass for men of more than common strength, by drawing against horses, breaking ropes, lifting vast weights, &c. though they could in none of the postures really perform so much as *Joyce*, yet they did enough to amaze and amuse, and get a deal of money, so that every two or three years we had a *new second* Sampson.

"About fifteen years ago a German of middle size, and but ordinary strength, showed himself at the *Plue Bosts*, in the Haymarket, and, by the contrivance above-mentioned, passed for a man of uncommon strength, and gained considerable sums of money by the daily concourse of spectators. After having seen him once, I guessed at his manner of imposing upon the multitude; and being resolved to be fully satisfied in the matter, I took four very curious persons with me to see him again, viz. the Lord Marquis of Tullibardin, Dr Alexander Smart, Dr Pringle, and a mechanical workman, who used to assist me in my courses of experiments. We placed ourselves in such manner round the operator, as to be able to observe nicely all that he did; and found it so practicable, that we performed several of his feats that evening by ourselves, and afterwards I did the most of the rest, as I had a frame to sit in to draw, and another to stand in and lift weights, together with a proper girdle and hooks. I likewise showed some of the experiments before the Royal Society; and ever since, at my experimental lectures, I explain the reason of such performances, and take any person of ordinary strength that has a mind to try, who can easily do all that the German above mentioned used to do, without any danger or extraordinary straining, by making use of my apparatus for that purpose.

"In order to explain how great feats may be performed by men of no extraordinary strength, I have in fig. 79, drawn the lower part of a skeleton, containing so many of the bones of the human body as are concerned in these operations, making the figure pretty large, to show the better how the girdle is to be applied.

"The bones marked I S A P H I,* which compose the cavity called the pelvis, contain a bony circle or double arch of such strength, that it would require an immense force to break them by an external pressure directed towards the centre of the circle, or the middle of the pelvis. It is also to be observed, that those parts of this bony circumference, which receive the heads of the thigh-bone above, at, and below A, called the ischium or coxendix, are the strongest of all, so that a very great force may push the heads of the thigh-bones upwards, or, which is the same thing, the upper parts of the coxendix downwards, or towards each other in a lateral direction from A to A, without doing any hurt to the human body.

"Now if the girdle above described be put round the body in the manner represented in the figure, and be drawn downwards at G, by a great weight W, it will press on the os sacrum behind, and the ilium; then it will, by the pressure on T T, the great trochanters of the thigh-bones, draw the round heads the faster into their sockets, so as to make them less liable to slip out and strain the ligament by a push directed upward. So that the semicircular part of the girdle, T C S C T, presses together the bony arch denoted by the same letters, which, according to the nature of arches, is the stronger for that pressure. The abutments of the arch cannot come nearer together by reason of the resistance of the strong bones A P A, neither can they fly outwards, because the girdle keeps them together. Then the thighs and legs T D B are two strong columns, capable of sustaining 4000 or 5000 pounds at least, provided they stand quite upright. The muscles here are put to no strain, being no further concerned than to balance each other; that is, the antagonist muscles, extensors, and flexors, only keep the bones in their place, which makes them resist like one entire bone formed into an arch.

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* These bones are thus distinguished by anatomists: S, the os sacrum; I I, the ilium; A A, the os ischium; whose strongest part has on each side an hemispherical concave, in which the round head of the thigh-bone is received and turns round, being held by a strong ligament in its middle; those parts of the bone that join together before, betwixt A A and above P, are called the os pubis, or ossa pubis.

"This shows how easily the man, fig. 80, may sustain a cannon of 2000 or 3000 pounds weight. The same solution will also serve for the resistance of the man, fig. 81, whom five men, nay ten men, or two horses, cannot pull out of his situation when he sits so as to have his legs and thighs in the horizontal line P F, or in a line inclining downwards towards A, for then, though there is a difference in the sitting posture from the standing posture before described, yet by reason of the mobility of the heads of the thigh-bones, in the acetabula or cavities of the coxendix, the arch is the same and as strong as before, its abutments being equally supported by the legs and thighs. It is only the bending of the back-bone above the girdle to bring up the body which makes the difference of position in the man, though not sensibly in the resisting parts.

"In breaking a rope the muscles must act in extending the legs; and that we may the better explain that action, we must consider a man breaking the rope, as represented in fig. 82. Suppose a rope fastened to a post at P, or any other fixed point, is brought through an iron eye L, to the hook of the girdle H, of the man H I, and so fixed to it by a loop, or otherwise, as to be quite tight, whilst the man's knees are so bended as to want about an inch of having his legs and thighs quite upright. Then if the man on a sudden stretches his legs and sets himself upright, he will with ease break the very same rope which held two horses exerting their whole strength when they drew against him; such as a cart rope, or a rope of near three quarters of an inch diameter, which may be broken by a man of midding strength, by the action of the ten muscles* that extend the legs, five belonging to each leg.

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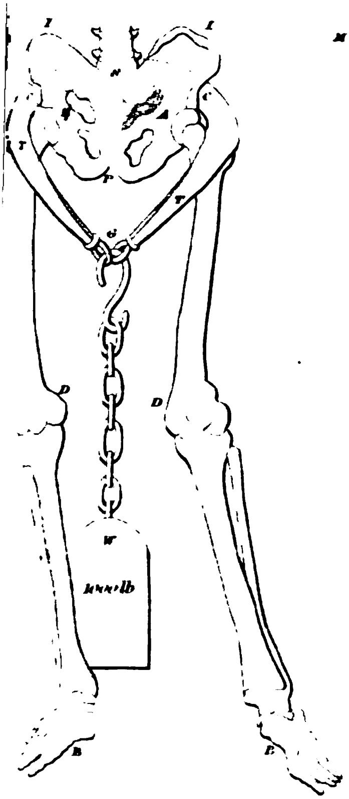
* The four muscles that extend each leg are described by anatomists thus :—1. The rectus, arising from the anterior inferior spine of the os ilium, and inserted, through the medium of the patella, into the anterior tuberosity of the tibia. 2. The cruralis, situated beneath the former, and arising from the front surface of the os femoris for a considerable extent, and inserted into the upper edge of the patella, and also, through the medium of that bone, into the anterior tuberosity of the tibia. 3. The vastus externus, arising from the root of the trochanter major, and outer side of the os femoris, and inserted into the outer edge of the patella, and again, through its medium, into the anterior tuberosity of the tibia. 4. The vastus internus which arises from

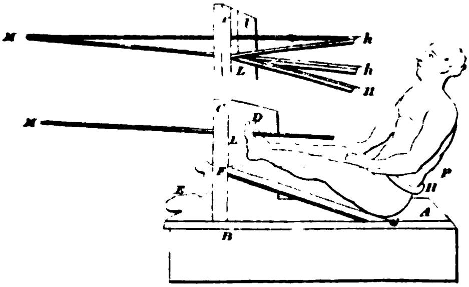
ANIMAL STRENGTH

From 79 to 84.

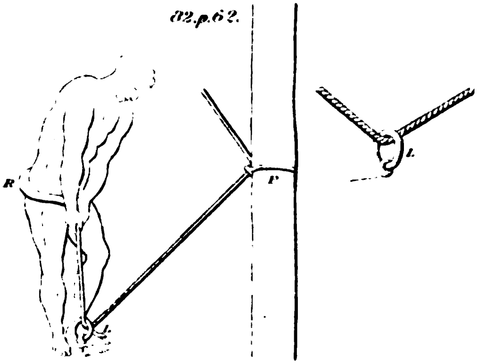
79. p. 61.



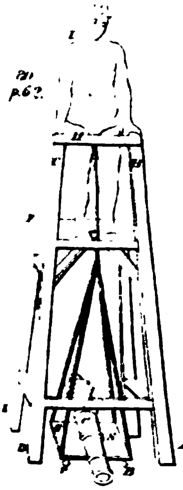
81. p. 62



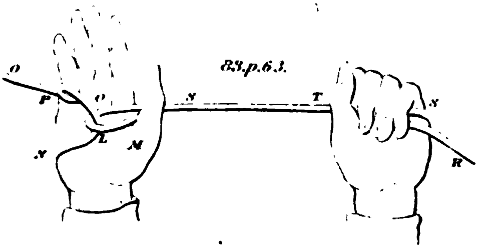
82. p. 62.



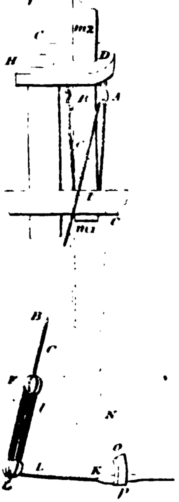
80 p. 62.



83. p. 63.



84. p. 64.



"In breaking the rope one thing is to be observed, which will much facilitate the performance; and that is, to place the iron eye L, through which the rope goes, in such a situation, that a plane going through its ring shall be parallel, or nearly parallel, to the two parts of the rope; because then the rope will in a manner be jammed in it, and not slipping through it, the whole force of the man's action will be exerted on that part of the rope which is in the eye, which will make it break more easily than if more parts of the rope were acted upon. So that the eye, though made round and smooth, may be said in some measure to cut the rope. And it is after this manner that one may break a whip-cord, nay, a small jack-line, with one's hand, without hurting it; only by bringing one part of the rope to cut the other; that is, placing it so round one's left hand, that, by a sudden jerk, the whole force exerted shall act upon one point of the rope. See fig. 83, where the cord to be broken at the point L in the left hand, is marked according to its course, by the letters R T S L M N O P Q, folding once about the right hand, then going under the thumb into the middle of the left hand; where crossing under another part, it is brought back under the thumb again to M, then round the back of the hand to N, so through the loop at L to O, and three times round the little finger at P and Q; which last is only that the loop N O may not give way. Before the hands are jerked from one another, the left hand must be shut, but the thumb must be held loose, lest pressing against the fore-finger it should hinder the part T L of the rope from carrying the force fully to the point L; but the little finger and that next to it must be held hard, to keep the loop N O firm in its place.

"There are several cases, wherein it would be of singular use to apply the force of one or more men, by means of the girdle or hook and chain, in the manner above-mentioned; as for example, when the resistance is very great, but the bodies that resist are to be removed but a little way: if we lift very heavy goods a small height, to remove any thing from under them; if we would draw a bolt or staple, and find we cannot do it even with an iron crow, the hand pulling it upwards at the end; then the hook of the girdle being applied at the end of the crow, the force exerted by stretching the legs would be tenfold of what the hands were able to do, without more help at the same place.

"There may also be many occasions on board a ship. I will

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the root of the trochanter minor, and inner surface of the os femoris, and inserted into the inner edge of the patella, and likewise, through its medium, into the anterior tuberosity of the tibia with the former muscles.

instance but one. Let F G, fig. 84, be the tackle for raising or lowering the main-top-mast, part of which is represented by *m* 1, *m* 2; the block G is fixed below, and as the block F comes down, it pulls along with it the top rope F B C, *m* 1 running over the block B, fixed at A, and round the block C in the heel of the top-mast, so as to draw up the lower end *m* 1 of the said main-top-mast, which, when hoisted up to its due height, is made fast by the iron pin or fid I, which is thrust through it, and then its own weight and the hole D of the cap will keep it in its place. We will suppose that the force required thus to raise the mast must be that of six men pulling upon deck at the fall of the tackle, that is, at the running rope F G K at K on the other side of the main-mast L *l*. Now in order to let down this mast on the sudden, as in case of hard weather, it is necessary the tackle and power must be made use of, though it be but to lift it a very little way, that a man may be able to get out the fid I, before the said mast can be let down and slip to N on the side of the main-mast. I say, that if the hands are so employed otherwise, that instead of six men there be only one man at the rope K; if he has a strong girdle to which he fastens it, or makes a bow in the rope itself, to fix it round the lower part of his back, &c., he may exert much more force in the direction G K than the six men in the common way of pulling; and if he draws to him, sitting on the ground, and pushing his feet against the first firm obstacle that he finds, as against O P, only two inches of the rope G K, he will raise up the main-top-mast the third part of an inch, which will be sufficient for the iron fid I to be drawn out." Desaguliers' *Philosophy*, vol. i.

WATER-MILLS.

Water-mill is the name by which all mills are designated that receive their motion from the impulse of the water. As each of these mills will come under their respective heads, we shall, in the present article, confine ourselves to a minute description of the different kinds of water-wheels, by whose axis the force with which they have been impressed may be transmitted to move any species of machinery, however simple or complex.

But, notwithstanding the extensive signification of the term water-mill, when applied to the different branches of manufacture carried on therein, we have another, and still more simple division, arising from the peculiar construction of the water-wheel, termed the undershot-mill, the overshot-mill, and the breast-mill. There is also another called the mill with horizontal wheels; but as this is very disadvantageous in point of practical utility, we shall forbear to describe it. The *undershot-wheel* is used only in streams, and is acted upon by the water striking the float-boards at the lower circumference of the wheel. In the *overshot-wheel* the water is poured over the top of the wheel, and is received in buckets formed all round the wheel for that purpose. And in the *breast-wheel* the water falls down upon the wheel at right angles to the float-boards, or buckets placed round the circumference of the wheel to receive it.

UNDERSHOT-WHEELS.

Mr John Smeaton has made numerous experiments upon the different kinds of water-wheels, the results of which were laid before the Royal Society. The time that has elapsed since the period when they were first given to the world, has been sufficient to prove their fallacy, if any had existed; and the high estimation in which they still continue to be held by mathematicians and mechanics, is certain evidence of their value and importance.

Mr Smeaton prefaces a minute description of the machines and models used by him for his experiments, with an observation, that what he has to communicate on the subject was originally deduced from experiments, which he looks upon as the best means of obtaining the outlines in mechanical inquiry. "But in such cases," says he, "it is very necessary to distinguish the circumstances in which a model differs from a machine in large; otherwise a model is more apt to lead us from the truth than towards it: and, indeed, though the utmost circumspection be used in this way, the best structure of machines cannot be fully ascertained but by making trials with them, when made of their proper size. It was for this reason, though the models and experiments referred to were made in the years 1752 and 1753, that I have deferred offering them to the Society until I had an opportunity of *putting the deductions made therefrom in real practice*, in a variety of cases, and for various purposes, so as to be able to assure the Society that *I have found them to answer*."

Mr Smeaton then remarks, that the word *power*, as used in practical mechanics, signifies the exertion of strength, gravitation, impulse, or pressure, so as to produce motion: and by means of strength, gravitation, impulse, or pressure, compounded with motion, to be capable of producing an effect;

and that no effect is properly mechanical, but what requires such a kind of power to produce it.

Having described the models and machines used for making his experiments, he observes that with regard to *power*, it is most properly measured by the raising of a weight, the relative height to which it can be raised in a given time being the actual extent; or, in other words, if the weight raised be multiplied by the height to which it can be raised in a given time, the product is the measure of the power raising it; and, consequently, all those powers are equal, whose products, made by such multiplication, are the same: for if a power can raise twice the weight to the same height, or the same weight to twice the height, in the same time that another power can, the first power is double the second; but if the power can only raise half the weight to double the height, or double the weight to half the height, in the same time that another can, those two powers are equal. This, however, must be understood to be only in cases of slow and equable motion, where there is no acceleration or retardation.

In comparing the effects produced by water-wheels with the powers producing them, or, in other words, to know what part of the original power is necessarily lost in the application, we must previously know how much of the power is spent in overcoming the friction of the machinery and the resistance of the air; also, what is the real velocity of the water at the instant that it strikes the wheel, and the real quantity of water expended in a given time.

From the velocity of the water at the instant that it strikes the wheel, the height of head productive of such velocity can be deduced, from acknowledged and experimental principles of hydrostatics: so that by multiplying the quantity or weight of water really expended in a given time, by the height of a head so obtained, which must be considered as the height from which that weight of water had descended in such given time, we shall have a product equal to the original power of the water, and clear of all uncertainty that would arise from the friction of the water, in passing small apertures, and from all doubts arising from the different measure of spouting waters, assigned by different writers.

On the other hand, if the sum of the weights raised by the action of this water, and of the weight required to overcome the friction and resistance of the machine, be multiplied by the height to which the weight can be raised in the time given, the product will be equal to the effect of that power; and the proportion of the two products will be in proportion of the *power* to the *effect:* so that by loading the wheel with different weights successively, we shall be able to determine at what particular load, and velocity of the wheel, the effect is a *maximum*.

The experiments made by Mr Smeaton may thus be reduced. The circumference of the wheel, 75 inches, multiplied by 86 turns, gives 6450 inches for the velocity of the water in a minute; $\frac{1}{60}$ of which will be the velocity in a second, equal to 107.5 inches, or 8.96 feet, which is due to a head of 15 inches; and this we call the *virtual* or *effective head*. The area of the head being 105.8 inches, this multiplied by the weight of water of the cubic inch, equal to the decimal 579 of the ounce avoirdupois, gives 61.26 ounces for the weight of as much water as is contained in the head, upon one inch in depth, $\frac{1}{16}$ of which is 3.83 pounds; this multiplied by the depth 21 inches, gives 80.43 pounds for the value of 12 strokes; and by proportion, 39½ (the number made in a minute,) will give 264.7 pounds, the weight of water expended in a minute.

Now as 264.7 pounds of water may be considered as having descended through a space of 15 inches in a minute, the product of these two numbers 3970 will express the *power* of the water to produce mechanical effects; which were as follows:

The velocity of the wheel at the *maximum*, as appears above, was 30 turns a minute; which multiplied by nine inches, the circumference of the cylinder, makes 270 inches; but as the scale was hung by a pulley and double line, the weight was only raised half of this, viz. 135 inches.

	lb.	*oz.*
The weight in the scale at the maximum . .	8	—
The weight of the scale and pulley	—	10
The counterweight, scale, and pulley . . .	—	12
Sum of the resistance . . .	9	6
Or pounds . .	9.375	

Now as 9.375 pounds is raised 135 inches, these two numbers being multiplied together, the product is 1266, which expresses the effect produced at a maximum; so that the proportion of the *power* to the *effect* is as 3970 : 1266, or as 10 : 3.18.

But though this is the greatest single effect producible from the power mentioned, by the impulse of the water upon an undershot-wheel; yet, as the whole power of the water is not exhausted by it, this will not be the true ratio between the *power* of the water, and the *sum* of all the *effects* producible therefrom; for, as the water must necessarily leave the wheel with a velocity equal to the wheel's circumference, it is plain some part of the power of the water must remain after quitting the wheel.

The velocity of the wheel at the maximum is 30 turns a minute; and consequently its circumference moves at the rate of 3.123 feet a second, which answers to a head of 1.82 inches; this being multiplied by the expense of water in a minute, viz. 264.7 pounds, produces 481 for the power *remaining* in the water after it has passed the wheel: this being therefore deducted from the original power 3.970, leaves 3.489, which is that *part* of the power spent in producing the effect 1266; and consequently, the part of the power spent in producing the effect, is to the greatest effect that it produces as 3489 : 1266 : : 10 : 3.62, or as 11 to 4.

The *velocity of the water* striking the wheel has been determined to be equal to 86 circumferences of the wheel per minute, and *the velocity of the wheel* at the *maximum* to be 30; the velocity of the water will therefore be to that of the wheel as 66 to 30, or as 10 to 3.5, or as 20 to 7.

The *load at the maximum* has been shown to be equal to nine pounds six ounces, and the wheel ceased moving with 12 pounds in the scale: to which if the weight of the scale be added, viz. 10 ounces, the proportion will be nearly as 3 to 4 between the load at the *maximum* and *that* by which the wheel is stopped.

It is somewhat remarkable, that though the velocity of the wheel in relation to the water turns out greater than $\frac{1}{3}$ of the velocity of the water, yet the impulse of the water in the case of a *maximum* is more than double of what is assigned by theory; that is, instead of $\frac{4}{9}$ of the column, it is nearly equal to the whole column.

It must be remembered, therefore, that, in the present case, the wheel was not placed in an open river, where the natural current, after it has communicated its impulse to the float, has room on all sides to escape, as the theory supposes; but in a conduit or race, to which the float is adapted, the water cannot otherwise escape than by moving along with the wheel. It is observable, that a wheel working in this manner, so soon as the water meets the float, receives a sudden check, and rises up against the float, like a wave against a fixed object; insomuch, that when a sheet of water is not a quarter of an inch thick before it meets the float, yet this sheet will act upon the whole surface of a float whose height is three inches; and, consequently, were the float no higher than the thickness of the sheet of water, as the theory also supposes, a great part of the force would have been lost by the water dashing over the float.

Mr Smeaton next proceeds to give tables of the velocities of wheels with different heights of water; and from the whole deduces the following conclusions.

Maxim 1. That the virtual or effective head of water, and consequently its effluent velocity being the same, the mechanical effect produced by a wheel actuated by this water will be nearly in proportion to the quantity of water expended.

Note.—The virtual or effective head of any water which is moving with a certain velocity, is that height from which a heavy body must fall, in order to acquire the same velocity.

The height of the virtual head, therefore, may be easily determined from the velocity of the water; for the heights are as the square of the velocities, and the velocities, consequently, as the square roots of the heights. Mr Smeaton observed the velocity of the effluent water in all his experiments, and thence calculated the virtual head: he states, that the virtual head bears no proportion to the real head or depth of water; but that when either the aperture it greater, or when the velocity of the water issuing therefrom less, they approach nearer to a coincidence; and consequently, in the large openings of mills or sluices, where great quantities of water are discharged from moderate heads, the actual head of water, and the virtual head, as determined by theory from the velocity, will nearly agree.

For example of the application of his first maxim. Suppose a mill driven by a fall of water whose virtual head is five feet, and which discharged 550 cubic feet of water per minute, and that it is capable of grinding four bushels of wheat in an hour. Now another mill, having the same virtual head, but which discharges 1100 cubic feet of water per minute, will grind eight bushels of corn in an hour.

Maxim 2. That the expense of water being the same, the effect produced by an undershot-wheel will be nearly in proportion to the height of the virtual or effective head. This is proved in the preceding example.

Maxim 3. That the quantity of water expended being the same, the effect will be nearly as the square of the velocity of the water; that is, if a mill driven by a certain quantity of water, moving with the velocity of 18 feet per second, is capable of grinding four bushels of corn in an hour, another mill, driven by the same quantity of water, but moving with the velocity of 22½ feet per second, will grind nearly seven bushels of corn in an hour; because the square of 18 is 324, and the square of 22½ is 506¼. Now, say, as 324 is to 4 bushels, so is 506¼ to 6¼ bushels; that is as 4 to 6⅛.

Maxim 4. The aperture through which the water issues being the same, the effect will be nearly as the cube of the velocity of the water issuing; that is, if a mill driven by water rushing through a certain aperture with the velocity of 18 feet per second will grind four bushels of corn in an hour, another mill, driven by water moving through the same aperture, but with the velocity of 22½ feet per second, will grind 51 bushels; for the cube of 18 is 5832, and the cube of 22½ is 11390¾; then as 5832 is to 4, so is 11390¾ to 7⅘.

Maxim 5. The proportions between the power of the water expended, and the effect produced by the wheel, were 3 to 1. Upon comparing several experiments, Mr Smeaton fixed the proportions between them for large works; that is, if the weight of the water which is expended in any given time be multiplied by the height of the fall, and if the weight raised be also multiplied by the height through which it is raised, the first of these two products will be three times that of the second.

Maxim 6. The best general proportions of velocities between the water and the floats of the wheels will be that of 5 to 2; for instance, if the water when it strikes the wheel moves with a velocity of 18 feet per second, the wheel must be so loaded that its float-boards will move with a velocity of 7.2 feet per second, and the wheel will then derive the greatest power from the water, because as 5 to 18, so is 2 to 7.2.

Maxim 7. There is no certain ratio between the load that the wheel will carry when producing its maximum of effect, and the load that will totally stop it; but it approaches nearest to the ratio of 4 to 3, whenever the power exerted by the wheel is greatest, whether it arise from an increase of the velocity, or from an increased quantity of water; and this proportion seems to be the most applicable to large works. But when we know the effect which a wheel ought to produce, and the velocity it ought to move with whilst producing that effect, the exact knowledge of the greatest load it will bear is of very little consequence in practice.

Maxim 8. The load that the wheel ought to have, in order to work to the most advantage, can always be assigned thus: ascertain the power of the whole body of water, by multiplying the weight of the water expended in a minute by the height of the fall; take one-third of the product, and it gives the effect of power which the wheel ought to produce: to find the load, we must divide this product by the velocity which the wheel should have, and that, as we have before settled, should be two-fifths of the velocity with which the water moves when it strikes the wheel.

In the application of these principles the first thing to be done in a situation where an undershot-wheel is intended to be fixed, is to consider whether the water can run off clear from the wheel, 'so as to have no back-water to impede its motion; and whether the fall which can be obtained by constructing a proper dam to pen up the water, and sluice for it to pass through, will cause it to strike the float-boards of the wheel with sufficient velocity to impel them forcibly forwards; and also, whether the quantity of the supply will be sufficient to keep a wheel at work for a certain number of hours each day.

When we have ascertained the height of the fall of water, that is the height of the surface above the centre of the opening of the sluice, we must find what will be the continual velocity of the water issuing from such opening.

In some cases, we have the velocity of the water given when it issues from the opening of the sluice, and we then require to know what height of column will produce that velocity. These two things we may find by a single rule, and an easy arithmetical operation, which is as follows:

1st. The perpendicular height of the fall of water being given in feet and decimals of feet, the velocity that the water will acquire per second, expressed in feet and decimals, may be found by the following rule:

Multiply the constant number 64.2882 by the given height, and the square root of the product is the velocity required.

Example 1. If the height is two feet, the velocity will be found 11.34 feet per second.

Example 2. If the height is 16.0913 feet, the velocity will be 32.1826 feet per second.

Example 3. If the height is 50 feet, the velocity will be 56.68 feet per second.

Note.—The velocities thus obtained will be only the theoretic velocity; that is, the velocity any body would acquire by falling through such height *in vacuo;* the velocity in reality will be less, generally six or seven-tenths.

The uniform velocity of a fluid being given, expressed in feet and decimals of feet per second, the height of the column or fall to produce such a velocity may be found by the following rule:

Multiply the given velocity into itself, and divide the product by 64.2882; the quotient will be the height required, expressed in feet and decimals.

Example 1. If the velocity given is three feet per second, the height will be 0.139 of a foot.

Example 2. If the velocity given is 32.1826 feet per second, the height will be found 16.0913 feet.

Example 3. Let the velocity be 100 feet per second, the height will be 155.694 feet.

The knowledge of the foregoing particulars is absolutely necessary for constructing an undershot water-wheel; but the most advantageous method of setting it to work, and to find out the utmost it could perform, would be very difficult, if we were not furnished with the maximum which Mr. Smeaton settled, by showing, that an undershot water-wheel will act to the greatest advantage when the velocity of its float-boards is equal to two-fifths of four-tenth parts of that of the water which gives it motion.

LAMBERT'S WATER-WHEEL.

In 1819 Mr Lambert, of Prince's-street, Leicester-square, obtained a patent for an improvement in the water-wheel, which he thus describes:

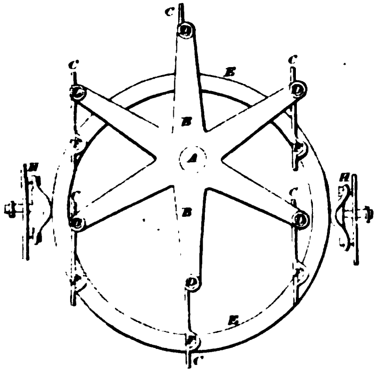
"My improved water-wheel, as shown in figs. 85, 86, and 87, represents the paddles standing in a vertical position to the surface of the water through which they are to pass, and in whatever situation or direction the wheel either rests or moves, the paddles preserve the same vertical position. The great advantage derived from the paddles of a water-wheel entering and quitting the water through which such wheel revolves in a perpendicular direction, has long been admitted to be a most important and desirable measure in that class of water-wheels known and called by engineers undershot-wheels, either for water-mills or for navigable purposes. The benefit of working the paddles of such wheels in a vertical position is not only the superior hold and pressure which the water takes on the paddles or floats of such wheels, but the very little back-water which they create on leaving it. The principle of this improvement is to make the lower paddles recede from the centre of the axle and to the arms to which they are attached, while the upper paddles proceed to the centre of the axle in equal distances as the others recede; and in the rotation of the wheel, every paddle passes through the various evolutions and positions to which every revolution of the wheel subjects each paddle. The lower paddles describe a greater radius of a circle than the upper paddles, and thereby travel at an increased velocity, or rather they pass at their extreme points through a greater space in the same period of time; this effect renders the lower half of the wheel heavier than the upper, by the eccentric position of the paddles, and the flat ring of iron to which they are attached, and it also increases the speed of any navigable body through the water to which such wheels are applied.

Figs. 85, 86, and 87, are views of my improved wheel with one paddle, as in fig. 85, at its greatest depth in the water; B, B, B, B, is one of the iron arm frames to which one end of the paddles, C, C, C, C, C, C, are attached by the joint-pins D, D, D, D, D, D, to the arm frames B, B, B, B. E E is the flat iron ring or eccentric circle, to which the other ends of the paddles are attached by similar joint-pins F, F, F, F, F, F. G G, are the iron guard or guide-rollers, a section of one of which is shown at fig. 88, which may either revolve on fixed axles, or these rollers may be fixed on revolving axles, whichever is most convenient. The object of these rollers is, to keep the iron circle E E in its proper situation, which is an equal distant position from the centre of the wheel-shaft in a longitudinal direction, and eccentric in a vertical position to the shaft A. These rollers must be placed apart from each other, a distance exactly equal to the diameter of the iron circle E E, consequently the rollers G G must be placed in a line through the centre of the circle E E, and which will allow this circle to rub and give motion to the rollers G G, at the speed it revolves. The circle E E forms an eccentric course, while it rubs on every part of its periphery against the rollers G G. This circle E E may be formed with teeth like the rim of a cog-wheel, and in that case the rollers G G may either one or both of them be formed into spur pinions to fit the teeth of the circle E E, which would be a quick and simple mode for my improved water-wheel to work machinery. I sometimes use two flat, hardened steel springs, as shown in fig. 89, instead of the rollers G G, to keep the circle E E in its proper place; and in certain situations they will be found to answer very well. Great care must be taken to make the joint pin-holes in the iron frames B, B, B, B, exactly an equal distance apart from each other; and it must also be observed in piercing or drilling the joint pin-holes in the circle E E, that they correspond with the holes made in the arm frames B, B, B, B. It will be always advisable to drill both the arm frames, B, B, B, B, and the circle E E, together, that the joint pin-holes in all three may correspond exactly with each other, and particularly from the centre of each. The joint pin-holes, in the paddle-plates or floats, should also be made to correspond with each other; and it is the distance of the holes from D to F in the paddles C C, as shown at fig. 90, which determine the eccentrity of the course of the iron ring E E; and it is by connecting these paddles at D to the arm frames B, B, B, B, and at F to the ring E E, which in the rotation of the whole by the axle A, and by keeping the circle E E in its proper situation as before described, either by the rollers G G, or when the springs H H are substituted for the rollers, that the paddles always preserve a vertical position to the surface of the water, and which cause the upper paddles to approach, whilst the lower paddles recede from the centre of the axle A. Fig. 86 represents a view of the wheel combined with all the paddles connected to both frames of the wheel, with the iron ring or circle E E placed in the middle of the frames and between the sides of the paddles, with the joint-pins in their proper places, with the two lower paddles at their most extended distance from the centre of axle A, whilst the two upper paddles are brought to their nearest situation to that axle; the joint-pins must either have nuts and screws, or other proper fastenings, to keep them in their several places, or split keys, the latter of which I decidedly prefer. The axle A must be properly placed and secured in the iron frames B, B, B, B, in any of the ordinary modes which an experienced and skilful workman will adopt. The number of sets of paddles or floats for any one wheel must be determined according to the magnitude and duty of such wheel; it is the general construction and combination as described, which constitute my improved wheel, and not the number of the paddles or floats, or their magnitude. I should, however, never recommend less than six sets of paddles or floats to be combined in any wheel made on the plan of my improved wheel, although I am aware it would act with a less number, but not so advantageously. The same letters in figs. 85, 86, and 87, represent the same

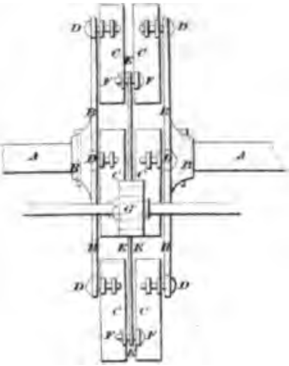
WATER WHEELS

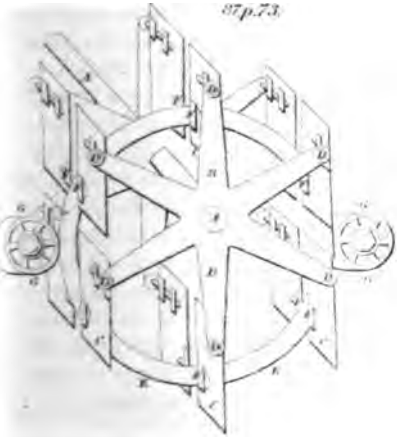
From 85 to 93.

85.p.73.

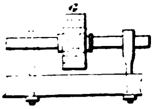


86.p.73.

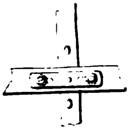




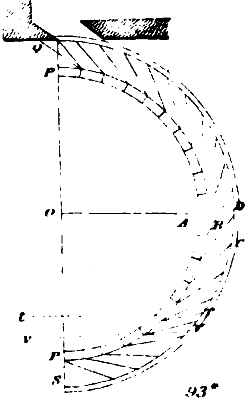
88.p.73.



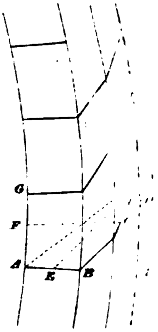
89.p.73.



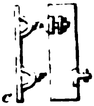
91.p.75.



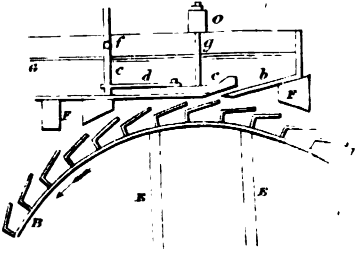
92.p.7



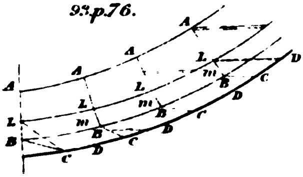
90.p.75.



93*



93.p.76.



parts in either of these figures, and as far as any of the similar parts are shown in figs. 88, 89, and 90, the letters and characters also distinguish them.

THE OVERSHOT-WHEEL.

This wheel consists of a frame of open buckets, placed round the rim of a vertical wheel, to receive the water from a spout placed over it, so that the buckets on the one side shall be always loaded, while those on the opposite side are empty. The loaded side will of course descend, and the wheel in its revolution will bring the empty buckets under the spout, to be in their turn filled with water.

The principal thing to be attended to in the construction of this wheel is to have the buckets of such a form as will retain the water along the greatest circumference of the wheel: and as this is a thing not easily to be accomplished, numerous contrivances have been restored to by mill-wrights to determine the best possible form.

Fig. 91 is the outline of a wheel having 40 buckets. The ring of board contained between the concentric circles Q D S and P A R, making the ends of the buckets, is called the shrouding, and Q P the depth of shrouding. The inner circle P A R is called the sole of the wheel, and usually consists of boards nailed to strong wooden rings of compass timber of considerable scantling, firmly united with the arms or radii. The partitions, which determine the form of the buckets, consists of three different planes or boards, A B, B C, C D, which are variously named by different artists. We have heard them called the start or shoulder, the arm, and the wrest: (probably for wrist, on account of a resemblance of the whole line to the human arm:) B is also called the elbow.

Fig. 92 represents a small portion of the same bucketing on a larger scale, that the proportion of the parts may be more distinctly seen. A G the sole of one bucket is made about $\frac{1}{5}$ more than the depth G H of the shrouding. The start A B is $\frac{1}{3}$ of A I. The plane B C is so inclined to A B that it would pass through H; but it is made to terminate in C, in such a manner that F C is $\frac{5}{6}$ths of G H or A I. Then C D is so placed that H D is about $\frac{1}{5}$th of I H.

By this construction it follows that the area F A B C is very nearly equal to D A B C; so that the water which will fill the space F A B C will all be contained in the bucket when it shall come into such a position that A D is a horizontal line; and the line A B will then make an angle of

35° with the vertical, or the bucket will be 35° from the perpendicular, passing through the axis of motion. If the bucket descend so much lower that one-half of the water runs out, the line A B will make an angle of 25° or 24° nearly with the vertical. Therefore the wheel, filled to the degree now mentioned, will *begin* to lose water at about $\frac{1}{8}$th of the diameter from the bottom, and *half of the water will be discharged* from the lowest bucket about $\frac{1}{12}$th of the diameter further down. Had a greater proportion of the buckets been filled with water when they were under the spout, the discharge would have begun at a greater height from the bottom, and we should lose a greater portion of the whole fall of water. The loss by the present construction is less than $\frac{1}{10}$th, (supposing the water to be delivered into the wheel at the very top,) and may be estimated at about $\frac{1}{12}$th; for the loss is the versed sine of the angle which the radius of the bucket make with the vertical. The versed sine of 35° is nearly $\frac{1}{5}$th of the radius, being 0.18085 or $\frac{1}{10}$th of the diameter. It is evident, that if only $\frac{1}{2}$ or this water were supplied to each bucket as it passes the spout, it would have been retained for 10° more of a revolution, and the loss of fall would have only been about $\frac{1}{18}$th.

These observations serve to show in general, that an advantage is gained by having the buckets so capacious that the quantity of water which each can receive as it passes the spout may not nearly fill it. This may be accomplished by making them of a sufficient length, that is, by making the wheel sufficiently broad between the two shroudings.

Mr Robert Burns, of Cartside, in Renfrewshire, has made what appeared to be a very considerable improvement in the construction of the bucket. The principle of this improvement consisted in dividing the bucket by a partition of such a height, that the inner and outer portions of the bucket on each side were nearly of equal capacity. See fig. 93. The bucket consisted of a start A B, an arm B C, and a wrest C D, concentric with the rim, and was divided by the partition L M, concentric with the sole and rim. If these buckets be filled one-third, they will retain the whole of the water at 18°, and the half at 11°, from the bottom. These advantages however were found to be counterbalanced by disadvantages; and Mr Burns did never, we believe, put the construction in practice.

The velocity of an overshot-wheel is a matter of very great nicety; and authors, both speculative and practical, have arrived at very different conclusions respecting it. M. Belidor very strangely maintains, that there is a certain velocity related to that obtainable by the whole fall, which will procure to an overshot-wheel the greatest performance. Desaguliers, Smeaton, Lambert, De Parcieux, and others, maintain, that there is no such relation, and that the performance of an overshot-wheel will be the greater, as it moves more slowly by an increase of its load of work. Belidor again states, that the active power of water lying in a bucket-wheel of any diameter is equal to the impulse of the same water on the floats of an undershot-wheel, when the water issues from a sluice in the bottom of the dam. The other writers whom we have named assert, that the energy of an undershot-wheel is but one-half of that of an overshot, actuated by the same quantity of water falling from the same height. The most generally received opinion is, that the overshot-wheel does the more work, as it moves slower; and the following is the reasoning adduced to prove it. Suppose that a wheel has 30 buckets, and that six cubic feet of water are delivered in a second on the top of the wheel, and discharged, without any loss by the way, at a certain height from the bottom of the wheel. Let this be the case, whatever is the rate of the wheel's motion, the buckets being of a sufficient capacity to hold all the water which falls into them. Suppose this wheel employed to raise a weight of any kind, water for instance, in a chain of 30 buckets, to the same altitude and with the same velocity. Suppose, further, that when the load on the rising side of the machine is one-half of that on the wheel, the wheel makes four revolutions in a minute, or one turn in 15 seconds. During this time 90 cubic feet of water will have flowed into the 30 buckets, and each have received three cubic feet. In that case each of the rising buckets contains 1½ feet; and 45 cubic feet are delivered into the upper cistern during one turn of the wheel, and 180 cubic feet in one minute.

Now, suppose the machine so loaded, by making the rising buckets more capacious, that it makes only two turns in a minute, or one turn in 30 seconds; then each descending bucket must contain six cubic feet of water. If each bucket on the rising side contained three cubic feet, the motion of the machine would be the same as before. This is a point none will controvert. When two pounds are suspended to one end of a string which passes over a pulley, and one pound to the other end, the velocity of descent of the two pounds will be the same with that of a four pound weight, which is employed in the same manner to draw up two pounds. Our machine would therefore continue to make four turns in a minute, and would deliver 90 cubic feet during each turn, and 360 in a minute. But, by supposition, it is making only two turns in a minute; which *must* proceed from a greater load than three cubic feet of rising water in each rising bucket. The machine must, therefore, be raising *more* than 90 feet of water during one turn of the wheel, and more than 180 in a minute.

Thus it appears that if the machine is turning twice as slow as before, there is *more than twice the former quantity* in the rising buckets; and more will be raised in a minute by the same expenditure of power. In like manner, if the machine go three times as slow, there must be *more than three times* the former quantity in the rising buckets, and more work will be done.

But further we may assert, that the *more* we retard the machine to a certain practical extent, by loading it with more work of a similar kind, the greater will be its performance; and the truth of the assertion may be thus demonstrated. Let us call the first quantity of water in the rising bucket, Q; the water raised by four turns in a minute will be $4 \times 30 \times Q = 120\ Q$. The quantity in this bucket, when the machine goes twice as slow, has been shown to be greater than $2\ Q$; call it $2\ Q + x$; the water raised by two turns in a minute will then be $2 \times 30 \times (2\ Q + x) = 120 + 60\ x$. Suppose next, the machine to go four times as slow, making but one turn in a minute; the rising bucket must now contain more than twice the quantity $2\ Q + x$, or more than $4\ Q + 2\ x$, call it $4\ Q + 2\ x + y$. The work done by one turn in a minute will now be $30 \times (4\ Q + 2\ x + y) = 120\ Q + 60\ x + 30\ y$. By such an induction of the work accomplished, with any rates of motion we choose, it is evident that the performance of the machine increases with every diminution of its velocity that is produced by the mere addition of a similar load of work, or that it does the more work the slower it goes. This, however, is abstracting from the effects of the friction upon the gudgeons of the wheel, a cause of resistance which increases with the load, though not in the same ratio.

We have also supposed the machine to be in its state of permanent uniform motion. If we consider it only in the beginning of its motion, the result is still more in favour of slow motion: for, at the first action of the moving power, the inertia of the machine itself consumes part of it, and it acquires its permanent velocity by degrees, during which the resistances arising from the work, friction, &c. increase, till they exactly balance the pressure of the water; and after this the machine no longer accelerates. Now, the greater the power and the resistance arising from the work are, in proportion to the inertia of the machine, the sooner, it is obvious, will it arrive at its state of permanent velocity.

The preceding discussion only demonstrates in general the advantage of slow motion; but does not point out in any degree the relation between the rate of motion and the work performed, nor even the principles on which it depends. But this is not necessary for the improvement of practical mechanics. It is, however, manifest, that there is not, in the nature of things, a maximum of performance attached to any particular rate of motion which should, on that account, be preferred. All, therefore, that we have to do, is to load the machine, and thus to diminish its speed, unless other physical circumstances throw obstacles in the way: for there are such obstacles, as in all machines there are certain inequalities of action that are unavoidable. In the action of a wheel and pinion, though made with the utmost judgment and care, there are such inequalities. These increase by the changes of form occasioned by the wearing of the machine; and much greater irregularities arise from the subsultory motions of cranks, stampers, and other parts which move unequally or reciprocally. A machine may be so loaded as just to be in equilibrio with its work, in the favourable position of its parts: and when this changes into one less favourable, the machine may stop, or, at all events, hobble and work unequally. The rubbing parts thus bear long on each other, with enormous pressures, cut deep into each other, and increase friction: therefore such slow motions should be avoided. A little more velocity enables the machine to overcome those increased resistances by its inertia, or the great quantity of motion inherent in it. Great machines possess this advantage in a superior degree, and, consequently, will work steadily with a smaller velocity.

Mr Smeaton, in his Experimental Inquiry, previous to examining into the power and application of water, when acting by its *gravity on overshot-wheels*, says, " In reasoning without experiment, one might be led to imagine, that however different the mode of application is, yet that whenever the same quantity of water descends through the same perpendicular space, that the natural effective power would be equal, supposing the machinery free from friction, equally calculated to receive the full effect of the power, and to make the most of it: for if we suppose the height of a column of water to be 30 inches, and resting upon a base or aperture one inch square, every cubic inch of water that departs therefrom will acquire the same velocity or *momentum*, from the uniform pressure of 30 inches above it, that one cubic inch let fall from the top will acquire in falling down to the level of the aperture: one would therefore suppose, that a cubic inch of water, let fall through a space of 30 inches, and there impinging upon another body, would be capable of producing an equal effect by collision, as if the same cubic inch had descended through the same space with a slower motion, and produced its effects gradually. But however conclusive this reasoning may seem, it will appear, in the course of the following deductions, that the effect of the gravity of descending bodies is very different from the effect of stroke of such as are *non-elastic*, though generated by an equal mechanical power."

When Mr Smeaton had finished his experiments on undershot mills, he reduced the number of floats on the wheel, which were originally 24, to 12; which caused a diminution in the effect, on account of a greater quantity of water escaping between the floats and the floor: but a circular sweep being adapted thereto, of such a length, that one float entered the curve before the preceding one quitted it, the effect came so near that of the former, as not to give any hopes of advancing it by increasing the number of floats beyond 24 in this particular wheel.

In these experiments the head was six inches, and the height of the wheel 24 inches, so that the whole descent was 30 inches: the quantity of water expended in a minute was 96⅔ pounds, which, multiplied by 30 inches, gives the power = 2900. After making the proper calculations, the effect was computed at 1914; the ratio therefore of the *power* and *effect* will be as 2900 : 1914, or as 10 : 6.6, or as 3 to 2 nearly. But if we compute the power from the height of the wheel only, we shall have 96⅔ pounds, multiplied by 24 inches = 2320 for the *power*, and this will be to the effect as 2320 : 1914, or as 10 : 82, or as 5 to 4 nearly.

From another set of experiments the following conclusions were deduced:

1. The effective power of the water must be reckoned upon the whole descent, because it must be raised that height in order to produce the same effect a second time. The ratios between the *powers* so estimated, and the effects at the *maximum*, differ nearly from that of 10 to 7.6, to that

of 10 to 5.2, that is nearly from 4.3 to 4.2. In those experiments where the heads of water and quantities expended are least, the proportion is nearly as 4 to 3; but where the heads and quantities are greatest, it approaches nearer to that of 4 to 2; and by a medium of the whole, the ratio is that of 3 to 2 nearly. Hence it appears, that the effect of overshot-wheels is nearly double to that of the undershot, and, by consequence, that non-elastic bodies, when acting by their impulse or collision, communicate only a part of their original power, the remainder being spent in changing their figure in consequence of the stroke. The ultimate conclusion is, that the effects, as well as the powers, are as the quantities of water and perpendicular heights multiplied together respectively.

2. By increasing the head from 3 to 11 inches, that is, the whole descent from 27 inches to 35, or in the ratio of 7 to 9 nearly, the effect is advanced no more than in the ratio of 8.1 to 8.4, that is, as 7 to 7.26; and consequently the increase of effect is not one-seventh of the increase of perpendicular height. Hence it follows, that the higher the wheel is in proportion to the whole descent, the greater will be the effect; because it depends less upon the impulse of the head, and more upon the gravity of the water in the buckets: and if we consider how obliquely the water issuing from the head must strike the buckets, we shall not be at a loss to account for the little advantage that arises from the impulse thereof, and shall immediately see of how little consequence this impulse is to the effect of an overshot-wheel. This, however, like other things, is subject to limitation, for it is desirable that the water should have somewhat greater velocity than the circumference of the wheel, in coming thereon; otherwise the wheel will not only be retarded by the buckets striking the water, but a portion of the power will be lost by the water dashing over the buckets.

3. To determine the velocity which the circumference of the wheel ought to have in order to produce the greatest effect, Mr Smeaton observes, that the slower a body descends, the greater will be the portion of the action of gravity applicable to the producing a mechanical effeet, and, in consequence, the greater will be the effect. If a stream of water falls into the bucket of an overshot-wheel, it is there retained till the wheel by moving round discharges it, and consequently the slower the wheel moves, the more water each bucket will receive: so that what is lost in speed, is gained by the pressure of a greater quantity of water acting in the buckets

at once. From the experiments, however, it appeared, that when the wheel made about 20 turns in a minute, the effect was near upon the greatest. When it made 30 turns, the effect was diminished about $\frac{1}{20}$th part; and that when it made 40, it was diminished about ¼; when it made less than 18¼, its motion was irregular; and when it was loaded so as not to admit its making 18 turns, the wheel was overpowered by its load. It is an advantage in practice, that the velocity of the wheel should not be diminished further than will procure some solid advantage in point of power, because *cæteris paribus*, as the motion is slower, the buckets must be made larger, and the wheel being more loaded with water, the stress upon every part of the work will be increased in proportion. The best velocity for practice, therefore, will be such, as when the wheel made 30 turns in a minute, that is, when the velocity of the circumference is a little more than three feet in a second. Experience confirms that this velocity of three feet in a second is applicable to the highest overshot-wheels, as well as the lowest; and all other parts of the work being properly adapted thereto, will produce very nearly the greatest effect possible; it is also determined by experience, that high wheels may deviate further from this rule, before they will lose their power, by a given aliquot part of the whole, than low ones can be admitted to do. For a wheel of 24 feet high may move at the rate of six feet per second without losing any part of its power; and, on the other hand, the author had seen a wheel 33 feet high that moved very steadily and well, with a velocity but little exceeding two feet. The reason of the superior velocity of the 24 feet wheel seems to have been owing to the small proportion that the head, requisite to give the water the proper velocity of the wheel, bears to the whole height.

4. The maximum load of an overshot-wheel, is that which reduces the circumferences of the wheel to its proper velocity; which will be known by dividing the effect it ought to produce in a given time, by the space intended to be described by the circumference of the wheel in the same time; the quotient will be the resistance overcome at the circumference of the wheel, and is equal to the load required, the friction and resistance of the machinery included.

5. The greatest velocity of which the circumference of an overshot-wheel is capable, depends jointly upon the diameter of the height of the wheel, and the velocity of falling bodies; for it is plain that the velocity of the circumference can never be greater than to describe a semi-circumference,

while a body let fall from the top of the wheel will descend through its diameter; nor even quite so great, as a body descending through the same perpendicular space cannot perform the same in so small a time when passing through a semi-circle as would be done in a perpendicular line. Thus, if a wheel is 16 feet one inch in diameter, a body will fall through it in one second: this wheel therefore can never arrive at a velocity equal to the making one turn in two seconds; but, in reality, an overshot-wheel can never come near this velocity; for when it acquires a certain speed, the greatest part of the water is prevented from entering the buckets, and the rest, at a certain point of its descent, is thrown out again by the centrifugal force. As these circumstances depend chiefly upon the form of the buckets, the utmost velocity of overshot-wheels cannot be generally determined; and, indeed, it is the less necessary in practice, as it is in this circumstance incapable of producing any mechanical effect.

6. The greatest load an overshot-wheel will overcome, considered abstractedly, is unlimited or infinite; for as the buckets may be of any given capacity, the more the wheel is loaded, the slower it turns, but the slower it turns, the more will the buckets be filled with water; and, consequently, though the diameter of the wheel and quantity of water expended are both limited, yet no resistance can be assigned, which it is not able to overcome; but in practice we always meet with something that prevents our getting into infinitesimals. For when we really go to work to build a wheel, the buckets must necessarily be of some given capacity, and consequently such a resistance will stop the wheel, as it is equal to the effort of all the buckets in one semi-circumference filled with water. The structure of the buckets being given, the quantity of this effort may be assigned, but is not of much consequence in practice, as in this case also the wheel loses its power; for though here is the exertion of gravity upon a given quantity of water, yet being prevented by a counterbalance from moving, is capable of producing no mechanical effect, according to our definition. But, in reality, an overshot-wheel generally ceases to be useful before it is loaded to that pitch; for when it meets with such a resistance as to diminish its velocity to a certain degree, its motion becomes irregular; yet this never happens till the velocity of the circumference is less than two feet per second, where the resistance is equable.

The reader having now become acquainted with the valuable course of experiments made by Mr Smeaton, we shall next offer to his notice a few remarks upon the best mode of delivering water upon an overshot-wheel.

In wheels of this construction, it has been, and still is, the common practice, to allow the water to flow into the buckets at the highest point of the wheel; but this system is decidedly bad; for the centre of gravity of the upper bucket is direct over the axle of the wheel, and, consequently, any water poured into that bucket will, instead of creating a rotatory motion, cause a greater pressure upon the pivots of the axle. The greatest advantage would be obtained by causing the water to fall upon the wheel, at an angle of 42½ or 45 degrees, as then the power of the wheel will be augmented by the increased leverage. In constructing wheels upon this principle, however, great care must be taken to allow a sufficiency of room in buckets for the escape of air, otherwise the wheel will not act. The same observation is also applicable to breast-wheels; for we were once present, and witnessed an instance of this kind, at the first starting of a breast-wheel, in which the millwright, in order to obtain the greatest possible effect, had made the back-boards to fit so tight that no water or air could escape; the consequence of which was, the necessity of reducing the whole of the back-boards, to allow air enough to escape for the water to act freely upon the floats.

BURNS'S OVERSHOT-WHEEL WITHOUT A SHAFT.

This ingenious machine was invented and erected by the late Mr Burns, whose mechanical ingenuity we have already had occasion to admire. It is represented in two different sections, in figs. 95 and 96, and forms a large hollow cylinder by its buckets and sole, without having any shaft or axletree.

This wheel is 12½ feet diameter, and seven feet broad over all, and has 28 buckets. The gudgeon is six inches diameter, by 9 inches long. The flaunch is 1½ inch thick at the extreme points. The arms are of redwood fir, 6 inches square; one piece making two arms in length, where they cross one another at the wheel's centre, 1½ inch of the wood remaining in each, connecting the two opposite arms as one piece. The wheels were made by first fitting the gudgeon into a large piece of hard wood, with the flaunch parallel to the horizon, and in that position the arms and rings were trained and bound fast to it. All the grooves for starts or raisers, and buckets, were cut out before it was removed; first one piece was bolted to the flaunch at *a a*, and so of the others, leaving the distant openings for the cross bars that reach between each arm and its opposite arm. These bars or pieces were only 4 inches square, and were of good beech wood, turned round in the body. They were 10 inches square at each end, in which was fitted a strong nut for a bolt, 1¼ inch thick, to go through *b*, and connect the two sides together.

After the arms were trained and fixed right upon the gudgeons, the innermost ring was completed; the tenons were trained on the arms first, and the rings 4½ inches thick and 8 inches deep, put on by keys driven into the mortice. The remaining tenons were then reduced from 1¼ to 1 inch thick, and the outermost ring, only 3 inches thick by 6 inches deep, was firmly wedged thereon, and bound fast at the other ends by three strong wooden pins, as at C C; to the lower ring, the outside of the uppermost and undermost rings are flush, all the additional thickness of the lower ring projecting inside the buckets.

Some difficulty was found in laying the water properly into the buckets of this wheel, owing to the narrowness of the mouths of the buckets, by the high start or raiser, which was remedied by adopting the following plan.

The openings in the bottom of the troughing should be of iron, and so distant from each other that the water from them is thrown into two separate buckets. The iron curved parts should also be movable, to adjust the openings to the quantity of water necessary for the wheel. Unless the head of water is 12 or 14 inches above these openings, it will be difficult to give it the proper direction into the buckets, especially if the openings are pretty wide for them; for then it deviates the more down from the line of direction, and tends to retard the wheel, by striking on the outside of the bucket.

The openings from which the buckets are filled, ought to be 10 inches less in length than the buckets, *i. e.* five inches at each side, otherwise the water is apt to jerk over on each side of the wheel, as the edges of the bucket pass by.

The mode of making and finishing the wheel at Cartside requires very little workmanship, compared to the usual method; and any good joiner will do it as well as a millwright. The joiner finished Cartside wheel in six or seven weeks. The construction will be better understood from the following reference to the figures.

Fig. 95 represents three distinct transverse views. The part marked A supposes a part of the shrouding in section, showing the pins; the part marked B is a section of the wheel through any part of the buckets, and showing three of the ties, 1, 2, 3, in section. Part D shows the manner in which the exterior ends of the wheel are finished, also the gudgeons, flaunch, &c.

Fig. 96 is a longitudinal section of the wheel through one of the arms, showing the projection of the shrouding, the manner in which the arms of the wheel are connected together, and likewise the manner in which the ties are connected to the gudgeon.

CHAIN OF BUCKETS.

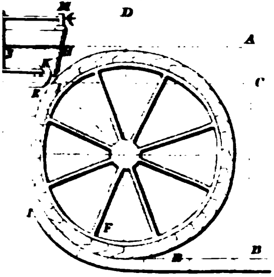
This is applicable in many situations where there is a considerable fall of water. This sketch was taken from one in Scotland used to give motion to a thrashing mill: the fig. 97 is so obvious as to need little explanation. The buckets C, D, G, H, &c. must be connected by several chains to avoid the danger of breaking, and united into an endless chain, which is extended over two wheels A and B, the upper one being the axis which is to communicate motion to the millwork; E is the spout to supply the water. The principal advantage of this plan is, that no water is lost by running out of the buckets before they arrive at the lowest part, as is the case with the wheel. Another is, that the buckets being suspended over the wheel A of small diameter, it may be made to revolve more quickly than a wheel of large diameter, and without increasing the velocity of the descending buckets beyond what is proper for them. This saves wheel-work when the machine is to be employed, as in a thrashing machine, to produce a rapid motion. On the other hand, the friction of the chain in folding over the wheel at the top, and seizing its cogs, will be very considerable; these cogs must enter the spaces in the open links between the buckets, to prevent the chain slipping upon the upper wheel. We think this machine might be much improved by contriving it so that the chain would pass through the centre of gravity of each bucket, whereas in the present form, the weight of each bucket tends to give the chain an extra bend.

The *chain-pump reversed*, has been proposed as a substitute for a water-wheel when the fall is very great, and we think it would answer the purpose with some chance of success. It would have an advantage over the chain-pump when employed for raising water, in the facility of applying cup leathers to the pistons on the chain, in the same way as other pumps, which leathers expand themselves to the inside of the barrel, and are kept perfectly tight by the pressure of the water. In the chain-pump such leathers cannot be

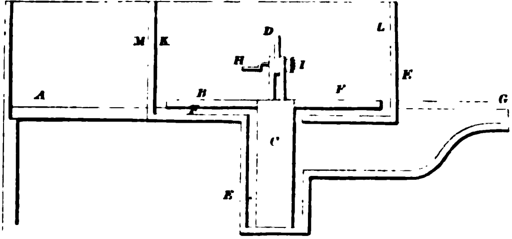
WATER WHEELS &c.

From 94 to 101

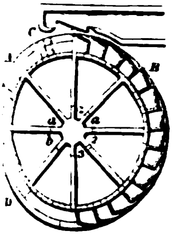
94.p.112.



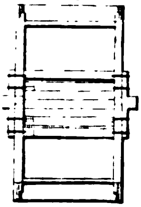
99.p.109.



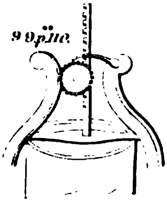
95.p.85.



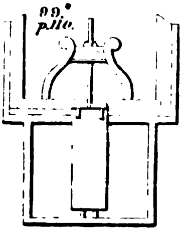
96.p.86.



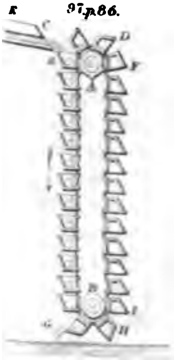
99.p.110.



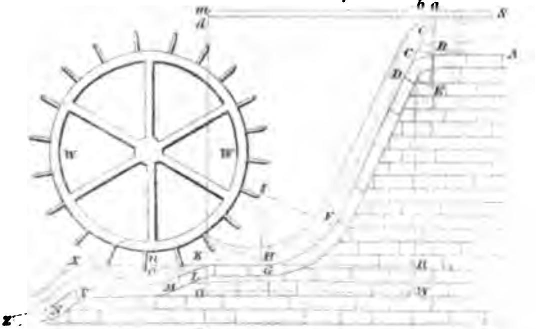
99.* p.110.



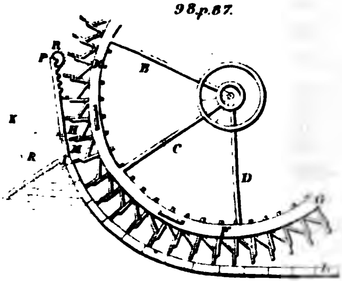
97.p.86.



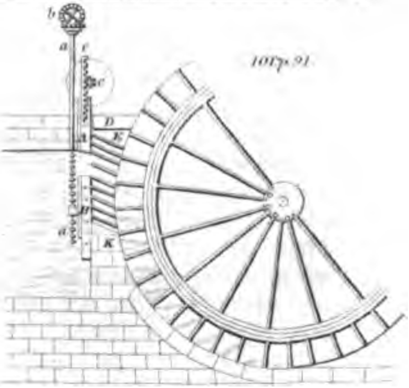
100.p.105.



98.p.87.



101.p.91.



employed, because the edges of the leather cups would turn down and stop the motion, when the cups were drawn upwards into the barrel. It is the defective mode of leathering the pistons of the chain-pump which occasions its great friction. In the motion of a machine of this kind, the pistons would descend into the barrel, and might therefore be leathered with cups like other pumps, so as to be quite tight without immoderate friction. This machine was proposed by a Mr Cooper in 1784, who obtained a patent for it, and Dr Robison has again proposed it with recommendation.

BREAST-WHEELS.

The breast-wheel partakes of the nature both of an overshot and an undershot: it is driven partly by impulse, but chiefly by the weight of water. The lower part of the wheel is surrounded by a curved wall or sweep of masonry, which is made concentric with the wheel, and the float-boards of the wheel are exactly adapted to the masonry, so as to pass as near as possible thereto without touching it; and the side walls are in like manner adapted to the end of the float-boards or sides of the wheel, the intention being to let the least possible quantity of water pass without causing the float-boards to move before it. In fig. 98, the water is poured upon the top of the wheel over the breasting at I, the efflux from the mill-dam K being regulated by the sluice or shuttle M, which is placed in the direction of a tangent to the wheel, and is provided with the rack R, and pinion P, by which it can be drawn up so as to make any required degree of opening, and admit more or less water to flow on the wheel.

The water first strikes on the float, and urges it by its impulse; but when the floats descend into the sweep, they form as it were close buckets, each of which will contain a given quantity of water, and the water cannot escape from these buckets except the wheel moves, at least this is the intention, and the wheel is fitted as close as it can be to the race with that view. Each of the portions of water contained in these spaces bears partly upon the wall of the sweep, and partly upon the floats of the wheel; and its pressure upon the floats, if not exceeded by the resistance, will cause the wheel to move; hence the action upon all the floats which are within the sweep of the breasting is by the weight of the water alone; but the water is made to impinge upon the first float-board with some velocity, because the surface of the water in the dam K is raised considerably above the orifice beneath the shuttle where the water issues.

The upper part of the fall at I is rounded off to a segment of a circle, called the crown of the fall, and the water runs over it. The lower edge of the shuttle when put down is made to fit this curve, so as to make a tight joint; and in consequence, when the shuttle is drawn up, the water will run between its lower edge and the crown in a sheet or stream which strikes upon the first float that presents itself, nearly in a direction perpendicular to the plane of the float-board, or of a tangent to the wheel. The float-boards of the wheel are directed to the centre, but there are other boards placed obliquely which extend from one float-board to the rim of the wheel, and nearly fill the space between one float-board and the next. These are called rising-boards, and the use of them is to prevent the water flowing over the float-board into the interior of the wheel; but the edges of these boards are not continued so far as to join to the back of the next float, because that would make all the boards of the wheel close, and prevent the free escape of the air when the water entered into the space between the floats.

As the water strikes with some force, the rising-boards are very necessary to prevent the water from dashing over the float-boards into the interior of the wheel.

This is the form of breast-wheel employed by Mr Smeaton in the great number of mills which he constructed; but although he speaks of the impulse of the water striking the wheel, he always endeavoured to make the top of the breasting, or crown of the fall, as high as possible; so as to attain the greatest fall and the least of the impulsive action. All rivers and streams of water are subject to variation in height from floods or dry seasons, and in some this is very considerable: it was therefore necessary to make the crown I of the fall, at such a height as that, in the lowest state of the water R, it would run over the crown in a sheet of three or four inches in thickness, and work the wheel. When the water rose higher in the mill-dam, it would then have a pressure to force it through, and in that case would strike the wheel so as to impel it by the velocity.

Mr Smeaton was well aware that the power communicated by this impulse was very small. In some cases, where the water was very subject to variation, he used a false or movable crown, that is, a piece of wood which fitted to the crown I, and raised the surface thereof a foot or more, so as to obtain the greatest fall when the water stood at a mean height; but when the water sunk too low to run over this movable crown, it could be drawn up to admit the water beneath it.

This effect has since been produced in a more perfect manner by making the crown of the fall a movable shuttle, to rise and fall according to the height of the water in the mill-dam, by which means the inconvenience before-mentioned is avoided.

IMPROVED BREAST-WHEEL, IN WHICH THE WATER RUNS OVER THE SHUTTLE.

Fig. 110 is a section of one of this kind. A is the water which is made to flow upon the float-board B, and urges the wheel by its weight only, the water being prevented from escaping or flowing off the float-boards by the breast or sweep D D, and the side-walls which enclose the floats of the wheel. The upper part of the breast D D is made by a cast-iron plate, curved to the proper sweep to line with the stone work. On the back of the cast-iron plate the moving shuttle *e* is applied; it fits close to the cast-iron, so as to prevent the water from leaking between them, and the water runs over its upper edge. F is an iron groove or channel let into the masonry of the side-walls, and in these the ends of the sliding shuttle are received: *f* is an iron rack, which is applied at the back of the shuttle, and ascends above the water-line where the pinion *g* is applied to it to raise or lower the shuttle. The axis of the pinion is supported in a frame of wood I I; *b* H is a toothed sector and balance-weight, which bears the shuttle upwards, or it might otherwise fall down by its own weight, and put the mill in motion when not intended. G is a strong planking, which is fixed across between the two side-walls, and retains the water when it rises very high, as in time of floods; but in common times the water rises only a few inches above the lower edge of the planking. When the shuttle is drawn up to touch this lower edge, the water cannot escape; but when the shuttle is lowered down, it opens a space *e*, through which the water flows upon the float-boards of the wheel.

Fig. 111 is a section of the *most improved form* for a breast-wheel, taken from the Royal Armoury Mills at Enfield Lock, erected by Messrs Lloyd and Ostel. The general description of this is like the former, but it is constructed in a better manner, and unites strength with durability. The breast of masonry is surmounted by a cast-iron plate A, 2½ feet high, which is let into the masonry of the side-walls at each end, and the lower part is formed with a flanch, by which it is bolted to the stone breast at top. This plate is made straight at the back for the shuttle B to lie against, and it slides up and down. The ends of the gate are guided by iron groove pieces or channels which are let into the stone-work of the side-walls, and being made wedge-like, they fix the ends of the cast-iron breast fast in its place. The grooves are not upright, but inclined to the perpendicular so much, that the plane of the gate is at right angles to a radius of the wheel drawn through the point where the water falls upon the wheel. D is a strong plank of wood, extended between the iron grooves just over the shuttle. When the shuttle is drawn up it comes in contact with the lower side of this piece of wood, and stops the water; but the piece D is fixed at such a height, that the water will run clear beneath it, unless its surface rises above its mean height.

The float-boards of the wheel do not point to the centre of the wheel, but are so much inclined thereto that they are exactly horizontal at the point where the water first flows upon them. In this way, the gravity of the water has its full effect upon the wheel, and the boards rise up out of the tail-water in a much better position than if they pointed to the centre of the wheel; this is more particularly observable when the wheel is flooded by tail-water penned up in the lower part of the race, so that it cannot run freely away from the wheel. The dimensions of this wheel are as follows: diameter 18 feet to the points of the floats, and 14 feet wide; the float-boards are 40 in number, each 16 inches wide, and each rising-board 11 inches wide. The wheel is formed of four cast-iron circles or wheels, each 14 feet 8 inches diameter, placed at equal distances upon the central axis, which is 14 feet 8 inches long between the necks or bearings, and 9 inches square; the bearing-necks are 9½ inches diameter. The wheel is calculated to make four revolutions per minute, which gives near 3½ feet per second for the velocity with which the float-boards move. The fall of water is six feet, and the power of the wheel, when the shuttle is drawn down one foot perpendicular, equal to 28-horse power.

BREAST-WHEEL WITH TWO SHUTTLES.

In this wheel the piece of wood marked D in the last figure, is fitted into the groove of the shuttle, and is provided with racks and pinions to slide up and down, independently of the lower shuttle. This enables the lower shuttle to rise and fall, according to the height of the water, so that the water shall always run over the top of it, in the proper quantity to work the mill with its required velocity, whilst the upper shuttle is only used to stop the mill by shutting it down upon the lower shuttle, and preventing the water from running over it. This plan is used when the mill is to be regulated by a governor, or machine to govern its velocity; in that case the governor is made to operate upon the lower shuttle, and will raise it up, or lower it down, according as the mill takes too much or two little water, and this regulates the supply; but the upper shuttle is used to stop the mill, and by this means the adjustment of the lower shuttle is not destroyed, but when set to work again, it will move with its required velocity. Fig. 101 is a section of one of the water-wheels at the cotton-mills of Messrs Strutt, at Belper, in Derbyshire. The width of this wheel is very great, and to render the shuttles A B firm, a strong grating of cast-iron is fixed on the top of the breast K, and the shuttles are applied at the back of the grating E, so as to slide up and down against it, the strain occasioned by the pressure of the water being borne by the grating. The lower shuttle is moved by means of long screws, *a*, which have bevelled wheels, *b*, at the upper ends, to turn them, by a connection of wheel-work with the wheel-work of the mill. The upper shuttle, A, is drawn up or down by racks and pinions, *c*, which are turned by a winch, or handle. The bars of the grating E are placed one above the other, like shelves, but are not horizontal; they are inclined, so that the upper surfaces of all the bars form tangents to an imaginary circle of one-third the diameter of the wheel described round the centre thereof. These bars are not above half an inch thick, and the spaces between them are 2½ inches. The bars are of a considerable breadth, the object of them being to lead the water, with a proper slope from the top of the lower shuttle B, to flow upon the floats of the wheel. This disposition allows the shuttles to be placed at such a distance from the wheel as to admit very strong upright bars of cast-iron to be placed between the wheel and the shuttles, for the shuttles to bear against, and prevent them from bending towards the wheel, as the great weight of water would otherwise occasion them to do. These upright bars are very firmly fixed to the stone-work of the breast at their lower ends, and the upper ends are fastened to a large timber, D, which is supported at its ends in the side walls, and has a truss-framing applied to the back of it, like the framing of a roof, to prevent it from bending towards the wheel. The upright bars are placed at distances of five feet asunder, so as to support the shuttles in two places in the middle of their length, as well as at both ends; and large rollers are applied in the shuttle, where it bears against these bars, to diminish the friction, which would otherwise be very great.

These precautions will not appear unnecessary when the size of the work is known. The wheel is 21⅓ feet in diameter, and 15 feet broad; the fall of water is 14 feet, when it is at a mean height; the upper shuttle is 2½ feet high, and 15 feet long; the lower shuttle is five feet high, and the same length, so that it contains 75 square feet of surface exposed to the pressure of the water; now taking the centre of pressure at two-thirds of the depth, or 3⅓ feet, we find the pressure equal to that depth of water acting on the whole surface; that is, the weight of 3⅓ cubic feet of water = 208 pounds, bears on every square foot of surface, which is equal to 15,600 pounds, or near seven tons, on the lower shuttle only; but if we take the two shuttles together, the surface is 112 square feet, and the mean pressure 312 pounds upon each, or 16 tons in the whole. The wheel has 40 float-boards pointing to the centre. The wheel is made of cast-iron. There are two wheels of the dimensions above stated, which are placed in a line with each other, and are only separated by a wall which supports the bearings; for they work together as one wheel, and the separation is only to obviate the difficulty of making one wheel of such great breadth as 30 feet, though this is not impossible, for there is a wheel in the same works 40 feet in breadth, but it is of wood and not iron, and is framed in a particular manner.—Dr Rees's *Cyclopædia*.

DR BAKKER'S MILL.

Dr Desaguliers appears to have been the first who published an account of this machine. He ascribes the invention to Dr Barker, in the following words: "Sir George Savill says, he had a mill in Lincolnshire to grind corn, which took up so much water to work it, that it sunk his ponds visibly, for which reason he could not have constant work; but now, by Dr Barker's improvement, the waste water only from Sir George's ponds keeps it constantly to work."

Dr Barker's mill is shown in fig. 102, where C D is a vertical axis, moving on a pivot at D, and carrying the upper millstone *m*, after passing through an opening in the fixed millstone C. Upon this axis is fixed a vertical tube T T, communicating with a horizontal tube A B, at the extremities of which A, B, are two apertures in opposite directions. When water from the millcourse M N is introduced into the tube T T, it flows out of the apertures A B, and, by the reaction or counterpressure of the issuing water, the arm A B, and consequently the whole machine is put in motion. The bridgetree *a b* is elevated or depressed by turning the nut *c* at the end of the lever *c b*. In order to understand how this motion is produced, let us suppose both the apertures shut, and the tube T T filled with water up to T. The apertures A, B, which are shut up, will be pressed outwards by a force equal to the weight of a column of water whose height is T T, and whose area is the area of the apertures. Every part of the tube A B sustains a similar pressure; but as these pressures are balanced by equal and opposite pressures, the arm A B is at rest. By opening the aperture at A, however, the pressure at that place is removed, and consequently the arm is carried round by a pressure equal to that of a column T T, acting upon an area equal to that of the aperture A. The same thing happens on the arm T B; and these two pressures drive the arm A B round in the same direction. This machine may evidently be applied to drive any kind of machinery, by fixing a wheel upon the vertical axis C D.

In the preceding form of Barker's mill, the length of the axis C D must always exceed the height of the fall N D, and therefore when the fall is very high, the difficulty of erecting such a machine would be great. In order to remove this difficulty, M. Mathon de la Cour proposes to introduce the water from the millcourse into the horizontal arms A, B, which are fixed to an upright spindle C T, but without any tube T T. The water will obviously issue from the apertures A, B, in the same manner as if it had been introduced at the top of a tube T T as high as the fall. Hence the spindle C D may be made as short as we please. The practical difficulty which attends this form of the machine, is to give the arms A, B, a motion round the mouth of the feeding pipe, which enters the arm at D, without any great friction, or any considerable loss of water. This form of the mill is shown in fig. 103, where F is the reservoir, K the millstones, K D the vertical axis, F E C the feeding pipe, the mouth of which enters the horizontal arm at C. In a machine of this kind which M. Mathon de la Cour saw at Bourg Argental, A B was 92 inches, and its diameter three inches; the diameter of each orifice was $1\frac{1}{8}$ inch, F G was 21 feet; the internal diameter of D was two inches, and it was fitted into C by grinding. This machine made 115 turns in a minute when it was unloaded, and emitted water by one hole only. The machine, when empty, weighed 80 pounds, and it was half supported by the upward pressure of the water.

This improvement, which was first given by M. Mathon de la Cour, in the *Journal de Physique*, 1775, appeared twenty years afterwards in the *American Philosophical Transactions*, as the invention of a Mr Ramsey; and Mr Waring, who inserted the account, contrary to every other philosopher, makes the effect of the machine only equal to that of a good undershot-wheel, moved with the same quantity of water falling through the same height.

Dr Gregory, in his *Mechanics*, vol. ii. has given this paper with some corrections, and recommends it as the best theory. The following rules, deduced from his calculus, may be of use to those who wish to make experiments on the effect of this interesting machine.

1. Make each arm of the horizontal rotatory tube or arm of any convenient length, from the centre of motion to the centre of the apertures, but not less than one-third, (one-ninth, according to Mr Gregory,) of the perpendicular height of the water's surface above their centres.

2. Multiply the length of the arm in feet by .6136, and take the square root of the product for the proper time of a revolution in seconds, and adapt the other parts of the machinery to this velocity; or if the required time of a revolution be given, multiply the square of this time by 1.629 for the proportional length of the arm in feet.

3. Multiply together the breadth, depth, and velocity per second, of the race, and divide the last product by 18.47 times, (14.27, according to Mr Gregory,) the square root of the height, for the area of either aperture.

4. Multiply the area of either aperture by the height of the fall of water, and the product by 41$\frac{2}{3}$ pounds, (55.775, according to Mr Gregory,) for the moving force, estimated at the centres of the apertures in pounds avoirdupois.

5. The power and velocity at the aperture may be easily reduced to any part of the machinery by the simplest mechanical rules.

TIDE-MILLS.

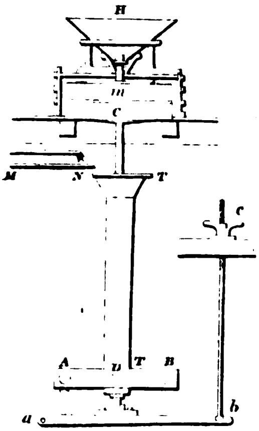
Tide-mills, as their name imports, are such as employ for their first mover the flowing and ebbing tide, either in the sea or a river.

Mills of this kind have not often, we believe, been erected in England, though several of our rivers, and particularly the Thames, the Humber, and the Severn, in which the tide rises to a great height, furnish a very powerful mover to drive any kind of machinery, and would allow of tide-mills

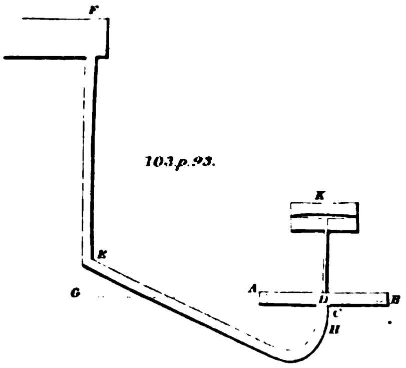
WATER WHEELS.

From 102 to 108

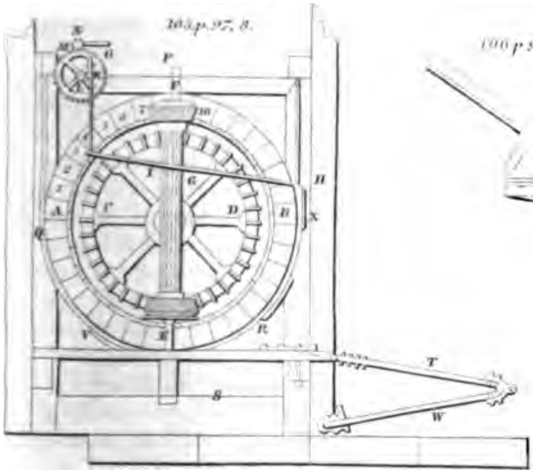
102.p.92.



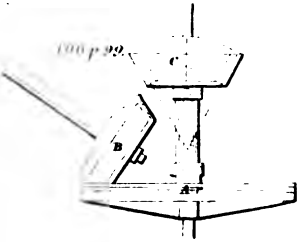
103.p.93.



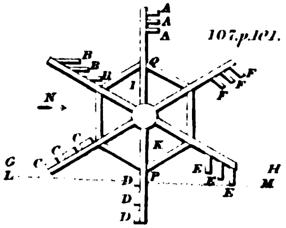
105.p.97.8.



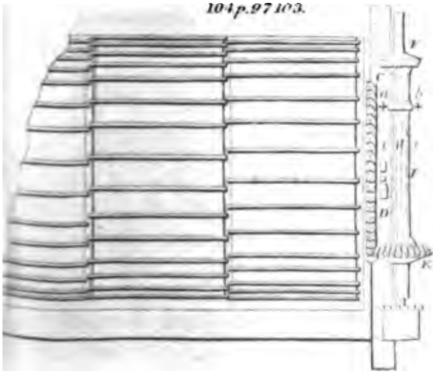
106.p.99.



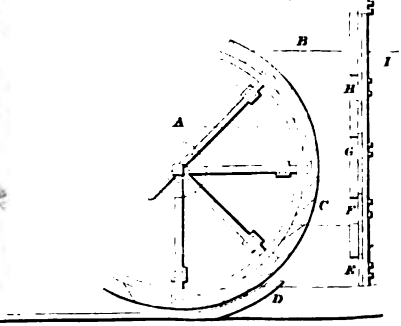
107.p.101.



104.p.97.103.



108.p.108.3.



being very advantageously constructed upon their banks. The erection of such mills is not to be recommended universally, as they are attended with a considerable original expense; beside that, some of their parts will require frequent repairs: but in some places, where coal is very dear, they may, on the whole, be found less expensive than steam-engines to perform the same work, and may, on that account, be preferred even to them.

We have not been able to ascertain who was the first contriver of a tide-mill in this country, nor at what time one was first erected. The French have not been so negligent respecting the origin of this important invention, as to let it drop into obscurity; but have taken care to inform us that such mills were used in France early in the last century. Belidor mentions the name of the inventor, at the same time that he states some peculiar advantages of this species of machine. "L'on en attribue," says he, "la première invention à un nommé *Perse*, maître charpentier de Dunkerque, que mérite assurément beaucoup d'éloge, n'y ayant point de gloire plus digne d'un bon citoyen, que celle de produire quelqu'invention utile à la société. En effet, combien n'y a-t'-il point de choses essentielles à la vie, dont on ne connoît le prix que quand on en est privé: les moulins en général sont dans ce cas-là. On doit sçavoir bon gré à ceux qui nous ont mis en état d'en construire partout: par exemple, à Calais, comme il n'y serpente point de rivières, on n'y a point fait jusqu'ici de moulins à eau, et ceux qui vont par le vent chômant une partie de l'année, il y a des tems où cette ville se trouve sans farine, et j'ai vu la garnison en 1730, obligé de faire venir du pain de Saint-Omer, au lieu qu'en se servant du flux et reflux de la mer, on pourrait construire autant de moulins à eau que l'on voudroit: il y a d'autres villes dans le voisinage de la mer sujettes au même inconvénient, parcequ'apparemment elles ignorent le moyen d'y remédier."

Mills to be worked by the rising and falling of the tide, admit of great variety in the essential parts of their construction; but this variety may perhaps be reduced to four general heads, according to the manner of action of the water-wheel. 1. The water-wheel may turn one way when the tide rises, and the contrary when it falls. 2. The water-wheel may be made to turn always in one direction. 3. The water-wheel may fall and rise as the tide ebbs and flows. 4. The axle of the water-wheel may be so fixed as that it shall neither rise nor fall, though the rotatory motion shall be given to the wheel, while at one time it is only partly, at another completely, immersed in the fluid. In the mills we have examined, says Dr Gregory, the first and third of these divisions have been usually exemplified in one machine; and the second and fourth may readily be united in another: we shall, therefore, speak of them under two divisions only.

1. When the water-wheel rises and falls, and turns one way with the rising tide, and the contrary when it ebbs. In order to explain the nature of this species of tide-mills, we shall describe one which has lately been erected on the right bank of the Thames, at East-Greenwich, under the direction of Mr John Lloyd, an ingenious engineer of Brewer's-green, Westminster.

This mill is intended to grind corn, and works eight pair of stones. The side of the mill-house parallel to the course of the river, measures 40 feet within; and as the whole of this may be opened to the river by sluice-gates, which are carried down to the low water-mark in the river, there is a 40 feet waterway to the mill: through the waterway the water presses during the rising tide into a large reservoir, which occupies about four acres of land; and beyond this reservoir is a smaller one, in which water is kept, for the purpose of being let out occasionally at low water to cleanse the whole works from mud and sediment, which would otherwise, in time, clog the machinery.

The water-wheel has its axle in a position parallel to the side of the river, that is, parallel to the sluice-gates which admit water from the river; the length of this wheel is 26 feet, its diameter 11 feet, and its number of float-boards 32. These boards do not each run on in one plane from one end of the wheel to the other, but the whole length of the wheel is divided into four equal portions, and the parts of the float-boards, belonging to each of these portions, fall gradually one lower than another, each by one-fourth of the distance from one board to another, measuring on the circumference of the wheel.

This contrivance, which will be better understood by referring to fig. 104, is intended to equalize the action of water upon the wheel, and prevent its moving by jerks. The wheel, with its incumbent apparatus, weighs about 20 tons, the whole of which is raised by the impulse of the flowing tide, when admitted through the sluice-gates. It is placed in the middle of the waterway, leaving a passage on each side of about six feet, for the water to flow into the reservoir, besides that which, in its motion, turns the wheel round. Soon after the tide has risen to the highest, (which at this mill is often 20 feet above the low water-mark,) the water is permitted to run back again from the reservoir into the river, and by this means it gives a rotatory motion to the water-wheel, in a contrary direction to that with which it moved when impelled by the rising tide: the contrivance by which the wheel is raised and depressed, and that by which the whole interior motions of the mill are preserved in the same direction, although that in which the water-wheel moves is changed, are so truly ingenious as to deserve a distinct description, illustrated by diagrams. Let, then, A B, (fig. 105,) be a section of the water-wheel, 1, 2, 3, 4, 5, &c. its floats; C D the first cog-wheel upon the same axis as the water-wheel; the vertical shaft F E carries the two equal wallower-wheels E and F, which are so situated on the shaft that one or other of them may, as occasion requires, be brought to be driven by the first wheel C D; and thus the first wheel acting upon F and E at points diametrically opposite, will, although its own motion is reversed, communicate the rotatory motion to the vertical shaft always in the same direction. In the figure the wheel E is shown in geer, while F is clear of the cog-wheel C D; and at the turn of the tide the wheel F is let into geer, and E is thrown out; this is effected by the lever G, whose fulcrum is at H, the other end being suspended by the rack K, which has hold of the pinion L on the same axle as the wheel M; into this wheel plays the pinion N, the winch O, on the other end of whose axle, furnishes sufficient advantage to enable a man to elevate or depress the wallower-wheels, as required.

The centre of the lever may be shown more clearly by fig. 104, where *a b* is a section of the lever, which is composed of two strong bars of iron, as *a b;* there are two steel studs or pins which work in the grooves of the grooved wheel I, this wheel being fixed on the four rods surrounding the shaft, of which three only can be shown in the figures, as *c d e;* the ends of these are screwed fast by bolts to the sockets of the wallower-wheels, and they are nicely fitted on the vertical shaft, so as to slide with little friction; thus the wallowers may be raised or lowered upon the upright shaft, while the gudgeon, on which it turns, retains the same position.

When the top wallower is in geer, it rests on a shoulder that prevents it from going too far down; and when the bottom one is in geer, there is a bolt that goes through the top wheel socket and shaft which takes the weight from the lever G, at the same time that it prevents much friction on the studs or pins of the lever which works in the grooved wheel I.

When the tide is flowing, after the mill has stopped a sufficient time to gain a moderate head of water, the fluid is suffered to enter and fall upon the wheel at the sluice Q, (fig. 105,) and the tail-water to run out at the sluice R.

The hydrostatic pressure of the head of water acting against the bottom of the wheel frame S, and at the same time acting between the folding-gates T W, which are thus converted into very large hydrostatic bellows, buoys up the wheel and frame, (though weighing, as before observed, nearly 20 tons,) and makes them gradually to rise higher and higher, so that the wheel is never, as the workmen express it, drowned in the flowing water; nor can the water escape under the wheel-frame, being prevented by the folding-gates, which pass from one end to the other of the wheel. In this way the wheel and frame are buoyed up by a head of four feet; and the mill works with a head of 5 or 5¼ feet.

When the tide is ebbing, and the water from the reservoir running back again into the river, it might, perhaps, be expected that in consequence of the gradual subsiding of the water, the water-wheel should as gradually lower; but lest any of the water confined between the wheel-frame at S, and the folding gates T W, should prevent this, there are strong rackworks of cast-iron, by which the wheel-frame can be either suspended at any altitude, or gradually let down so as to give the water returning from the reservoir an advantageous head upon the wheel; then the sluice R is shut, and V opened as well as X, the water entering at X to act upon the wheel, and flowing out at R. The upper surface of the wheel-frame is quadrangular, and at each angle is a strong cast-iron bar, which slides up and down in a proper groove, that admits of the vertical motion, but prevents all such lateral deviation as might be occasioned by the impulsion of the stream.

At each end of the water-wheel there is a vertical shaft, with wallowers and a first cog-wheel, as F E, and C D; and each of these vertical shafts turns a large horizontal wheel at a suitable distance above the wallowers, while each horizontal wheel drives four equal pinions placed at equal or quadrantal distances on its periphery, each pinion having a verticle spindle, on the upper part of which the upper millstone of its respective pair is fixed. Other wheels, driven by one or other of these pinions, giving motion to the bolting and dressing machines, and different subordinate parts of the mill.

Although the vertical shaft at each end of the water-wheel rises and falls with that wheel, yet the large horizontal wheel turning with such shaft does not likewise rise and fall, but remains always in the same horizontal plane, and in contact with the four pinions it drives. The contrivance for this purpose is very simple, but very efficacious; each great horizontal wheel has a nave, which runs upon friction-rollers, and has a square aperture passing through it vertically, just large enough to allow the shaft P to slide freely up and down in it, but not to turn round without communicating its rotatory motion to the wheel; thus the weight of the wheel causes it to press upon the friction rollers, and retain the same horizontal planes, and the action of the angles of the vertical shaft upon the corresponding parts of the square orifice in the nave causes it to partake of the rotatory motion, such motion being always in one direction, in consequence of the contrivance by which one or other of the wallowers E F is brought into contact with the opposite points of the first cog-wheel C D.

Several of the subordinate parts of this mill are admirably constructed; but we can only notice here the means by which the direction of the motion in the dressing and bolting machines may be varied at pleasure. On a vertical shaft are fixed, at the distance of about 15 or 18 inches, two equal cog-wheels, and another toothed-wheel, attached to a horizontal axle, is made so as to be movable up and down by a screw, and thus brought into contact with either the upper or lower of the two cog-wheels on the vertical shaft; thus, it is manifest, the motion is reversed with great facility by changing the position of the horizontal axle so that the wheel upon it may be driven by the two cog-wheels alternately. A wheel and pinion working at the other end of the horizontal axle will communicate the motion to the dressing machines.

Mr W. Dryden, Mr Lloyd's foreman, employed in the erection of this mill, suggests that a nearly similar mode may be advantageously adopted in working dressing machines in wind-mills; three wheels, all of different diameters, may be employed, two of them, as A and C, turning upon a vertical shaft, and the third, B, upon an inclined one. In fig. 106, the wheels A and B are shown in geer, while C is out; and if A be struck out by some such contrivance as is adopted with regard to the first cog-wheel and wallowers, (fig. 104 and 105,) C would come in contact with B, while A would be free, and so communicate a motion to B the reverse way. By this contrivance it would be easy, when the winds are strong and give a rapid motion to the vertical axle, to bring C to drive B, the wheel on the axle of the dressing-machines; and on the contrary, when the wind is slack, and the consequent motion of the machinery slow, let C be thrown out of geer, and the wheel B driven by the larger wheel A, as shown in the figure.

We should have been glad to see adopted in this well-constructed mill, a contrivance, recommended and pursued by the American mill-wrights, for raising the ground corn to the cooling-boxes or beaches from which it is to be conveyed into the bolting machine. In this mill, as in all we have seen, the corn is put into bags at the troughs below the mill-stones, and thence raised to the top of the mill-house by a rope, folding upon barrels turned by some of the interior machinery of the mill. In the American method, a large screw is placed horizontally in the trough which receives the flour from the mill-stones. The thread or spiral line of the screw is composed of pieces of wood about two inches broad and three long, fixed into a wooden cylinder seven or eight feet in length, which forms the axis of the screw. When the screw is turned round this axis, it forces the meal from one end of the trough to the other, where it falls into another trough, from which it is raised to the top of the mill-house by means of elevators, a piece of machinery similar to the chain-pump. These elevators consist of a chain of buckets, or concave vessels, like large tea-cups, fixed at proper distances upon a leathern band, which goes round two wheels, one of which is placed at the top of the mill-house, and the other at the bottom, in the meal-trough. When the wheels are put in motion, the band revolves, and the buckets, dipping into the meal-trough, convey the flour to the upper story, where they discharge their contents. The band of buckets is inclosed in two square boxes, in order to keep them clean, and preserve them from injury.

We shall now proceed,

2. To tide-mills, in which the axle of the water-wheel neither rises nor falls, and in which that wheel is made always to revolve in the same direction. A water-wheel of this kind must, manifestly, at the time of high tide, be almost, if not entirely, immersed in the fluid; and to construct a wheel to work under such circumstances is, obviously, a matter which requires no small skill and ingenuity.

The first persons who devised a wheel which might be turned by the tide, when completely immersed in it, were

Messrs Gosset and De la Deuille. Their wheel is described by Belidor in nearly the following terms. Suppose G H (fig. 107,) to denote the surface of the water at high-tide, the line L M the surface at low water, and that the current follows the direction of the arrow N; the problem is to construct the wheel so that it may always turn upon its axis I K. The figure just referred to is a profile of an assemblage of carpentry, which must be repeated several times along the arbor, according to the length which it is proposed to give to the float boards; and the planks or plates which compose these floats, must be hung to the other parts of the frame by as many joints as are necessary, to enable them to sustain the impulse of the water without bending. The sole peculiarity of this wheel consists in hanging upon the transverse beams in the frame-work, by hinges, the planks which are to compose the float boards; so that they may present themselves in face, as D, D, D, when they are at the bottom of the wheel, to receive the full stroke of the stream; and, on the contrary, they present only their edges, as A, A, A, when they are brought towards the summit of the wheel; hence, the water having a far greater effect upon the lower than the upper parts of the wheel, compels it to revolve in the order of the letters; instead of which, if the float-boards were fixed as in the usual way, the impulse of the fluid upon the wheel would be nearly the same in all its parts, and it would remain immovable.

We see, at once, that the boards D, D, D, having moved towards M, then begin to float, as at E, E, E, and more still at F, F, F, but that it is not till they arrive at A, A, A, that they attain the horizontal position; after that, having arrived at B, B, B, they begin to drop towards the beams to which they are hooked, and as soon as they have passed the level of the axle I K, the stream commences its full action upon them, which it attains completely between C, C, C, and E, E, E, and this, whether the surface of the water be at G H or at L M; for even in the latter case, it is manifest that the float-boards are entirely immersed when in the vertical position P Q. Belidor says, he was present at the first trial of such a wheel at Paris, and that it was attended with all the success that could be desired.

A water-wheel has been lately invented by Mr Dryden, which will work when nearly immersed in the water of a flowing tide. Fig. 108 is an elevation of this wheel, its upper parts being supposed to stand a foot or two higher than the tide ever rises; the axis of this wheel remains always in one place, and the wheel will work at high-water when the head is at B, and the tail-water at the dotted line A; it will also perform nearly the same work when the head is at C, and the tail-water level with the bottom of the wheel. The floats are all set at one and the same angle, with the respective radii of the wheel, as may be seen in the figure, and are made so as to have an opening of at least an inch between each float and the drum-boarding of the wheel. This opening is intended to prevent the wheel from being impeded by the tail-water; for as the bucket rises out of the water, there can be no vacuum formed in it, there being a full supply of air, in consequence of which the water leaves the wheel deliberately. The case is different with regard to wheels made in the common way; for if such are open wheels, the floats are made in such a manner as to throw the tail-water if they are immersed any depth in it; or, if they are close, the wheel wants proper vent for the air to prevent the formation of a vacuum in the rising bucket, or what is called by the miller "sucking up the tail-water." At D is planking made circular to fit the wheel pretty close for rather more than the space of two floats, so as to confine the water nearly close to the wheel. E, F, G, H, are sluices which are all connected together by the iron bar I, and lifted with the assistance of the wheel, two pinions, and a winch, the first pinion working into the rack K; these sluices are merely for stopping the wheel when occasion requires, although one might be sufficient to supply the wheel. The rings of this wheel may be made either of cast-iron or of wood; the floats may be iron plates rivetted together. The flanches on the arms of the wheel, exhibited in the sketch, are intended to facilitate the fixing of the first cog-wheels; the ring of the wheel may be fixed to the flanches at the extremity of the arms, and the large flanch made fast to the axle will receive the middle part of the wheel.

Fig. 109 is a plan of the house in which either of the two latter wheels may be fixed, showing in what manner the water may be conveyed always on one side of the wheel by the assistance of the four gates A, B, C, and D. When the mill is working from the river, A and B are open, the arrows point out the way the water runs from the river to the basin; and the dotted lines on the contrary the course from the basin to the river, when A, B, are shut, and C, D, opened. These gates are made to turn on an axle, which is about six inches from the middle of the gate, and on the top of the axle is a half-wheel; by some crane-work connected to it, the gate can be opened or shut at pleasure; when a head of water presses against the gates they will open great part of the way of themselves, by only letting the catches that keep them shut be lifted out of their place. X, Y, are two knees of cast-iron, to support the posts that the gates are fixed to. The walls of the building are represented at *a*, *b*, *c*, and *d*.

The reader will now be able to form an estimate of the comparative value and ingenuity of the two kinds of tide-mills here described. The simplicity of construction of the wheels of Gosset, De la Deuille, and Dryden, recommend them strongly; but we entertain some doubts of their being completely successful in practice: had the curious wheel, with the folding-gates, &c. fig. 104 and 106, been placed with its axle perpendicular, instead of parallel, to the course of the river, the water might then have always been admitted to act upon the same side of it, and the hydrostatic pressure would have operated as completely in lowering it continually during the time of ebb, as in raising it continually during the rising of the tide; thus, as appears to us, would the labour of a man be saved, who, according to the present construction, must attend the water-wheels; and all the additional apparatus now requisite to shift the spur-wheels, would at the same time be saved, and a consequent diminution of original expense. Dr Gregory's *Mechanics*, vol. ii.

In selecting a site for the erection of a mill, the engineer must be careful not to make choice of a spot that is liable to be flooded. When the water in the mill-tail will not run off freely, but stands pent up in the wheel-race, so that the wheel must work or row in it, the wheel is said to be tailed, or to be in back-water or tail-water; which greatly impedes the velocity of the wheel, and, if the flood be great, completely stops it.

Every mill that is well and properly constructed, will clear itself of a considerable depth of tail-water, provided there is, at the time, an increase in the height of the water in the mill-dam or head, and an unlimited quantity of water to draw upon the wheel. Common breast-mills will bear two feet of tail-water, when there is an increase of head, and plenty of water to be drawn upon the wheel, without prejudice to their performance; and mills that are well constructed, with slow moving wheels, will bear three and even four feet and upwards of tail-water. Mr Smeaton mentions having seen an instance of six feet; and it is a common thing in level countries, where tail-water is most annoying, to lay the wheel from six to twelve inches below the water's level of the pond below, in order to increase the fall of water; and, if judiciously applied, is attended with good effect, as it increases the diameter of the wheel, and though it must always work in that depth of tail-water, it will perform full as well, because the water ought to run off from the bottom of the wheel, in the same direction as the wheel turns.

ON THE CONSTRUCTION OF THE WHEEL-RACE AND WATER-COURSE.

The wheel-race should always be built in a substantial manner with masonry, and if the stones are set in Roman cement, it will be much better than common mortar. The earth, behind the masonry, should be very solid, and if it is not naturally so, it should be hard rammed and puddled, to prevent percolation of the water. This applies more particularly to breast-wheels, in which the water of the dam or reservoir is usually immediately behind the wall or breast in which the wheel works, a sloping apron of earth being laid from the wall in the dam to prevent the water leaking. The wall of the breast should have pile planking driven beneath, to prevent the water from getting beneath, because that might blow up the foundation of the race. The stones of the race are hewn to a mould, and laid in their places with great care; but afterwards, when the side-walls are finished, and the axis of the wheel placed in its bearings, a gauge is attached to it and swept round the curve, and by this the breast is dressed smooth, and hewn to an exact arch of a circle; the side-walls, in like manner, are hewn flat and true at the place where the float-boards are to work. It is usual to make the space between the side-walls two inches narrower at each side, in the circular part where the float acts, than in the other parts.

In some old mills the breast is made of wood planking, but this method has so little durability that it cannot be recommended.

In modern mills, the breast is lined with a cast-iron plate, but we do not approve of this, because it is next to impossible to prevent some small leakage of water through the masonry; and this water, being confined behind the iron breast, cannot escape, but its hydrostatic pressure to force up the iron is enormous; and if the water can ever insinuate itself behind the whole surface of the plate, rarely fails to break it, if not to blow it up altogether. This is best guarded against by making deep ribs projecting from the back of the plate, and bedding them with great care in the masonry; these not only strengthen the plate, but also cut off the communication of the water, so that it cannot act upon larger surfaces at once, than the strength and weight of the plate can resist. Stone is undoubtedly the best materials for a breasting. In overshot-wheels the loss of water, by running out of the buckets as they approach the bottom of the wheel, may be considerably diminished by accurately forming a sweep or casing round the lower portion of the wheel, so as to prevent the immediate escape of the water, and causing it to act in the manner of a breast-wheel. While this improvement remains in good condition, and the wheel works truly, it produces a very sensible effect; but it is frequently objected to, because a stick or a stone falling into the wheel would be liable to tear off part of its shrouding, and damage the buckets; and again, a hard frost frequently binds all fast, and totally prevents the possibility of working during its continuance; but we do not think the latter a great objection, for the water is not more liable to freeze there than in the buckets, or in the shuttle, and may be prevented by the same means, viz. by keeping the wheel always in motion, a very small stream of water left running all night will be sufficient. Mr Smeaton always used such sweeps, and with very good effect; it is certainly preferable to any intricate work in the form of the buckets.

Mill-courses.—As it is of the highest importance to have the height of the fall as great as possible, the bottom of the canal or dam which conducts the water from the river should have a very small declivity; for the height of the water-fall will diminish in proportion as the declivity of the canal is increased; on this account, it will be sufficient to make A B, fig. 100, slope about one inch in 200 yards, taking care to make the declivity about half an inch for the first 48 yards, in order that the water may have a velocity sufficient to prevent it from flowing back into the river. The inclination of the fall, represented by the angle G C R, should be 25° 50′; or C R, the radius, should be to G R, the tangent of this angle, as 100 to 48, or as 25 to 12; and since the surface of the water S *b* is bent from *a b* into *a c*, before it is precipitated down the fall, it will be necessary to incurvate the upper part B C D of the course into B D, that the water at the bottom may move parallel to the water at the top of the stream. For this purpose, take the points B, D, about 12 inches distant from C, and raise the perpendiculars B E, D E; the point of intersection E will be the centre, from which the arch B D is to be described; the radius being about 10$\frac{1}{6}$ inches.

Now, in order that the water may act more advantageously upon the float-boards of the wheel W W, it must assume a horizontal direction H K, with the same velocity which it would have acquired when it came to the point G: but, in falling from C to G, the water will dash upon the horizontal part H G, and thus lose a great part of its velocity; it will be proper, therefore, to make it move along F H, an arch of a circle, to which D F and K H are tangents in the points F and H. For this purpose, make G F and G H each equal to three feet, and raise the perpendiculars H I, F I, which will intersect one another in the points I, distant about four feet nine inches and $\frac{4}{10}$ths from the points F and H, and the centre of the arch F H will be determined. The distance H K, through which the water runs before it acts upon the wheel, should not be less than two or three feet, in order that the different portions of the fluid may have obtained a horizontal direction; and if H K be much larger, the velocity of the stream would be diminished by its friction on the bottom of the course. That no water may escape between the bottom of the course K H and the extremities of the float-boards, K L should be about three inches, and the extremity *o* of the float-board *n o*, should be beneath the line H K X, sufficient room being left between *o* and M for the play of the wheel, or K L M may be formed into the arch of a circle K M, concentric with the wheel. The line L M V, called by M. Fabre the course of impulsion, (le coursier d'impulsion,) should be prolonged, so as to support the water as long as it can act upon the float-boards, and should be about nine inches distant from O P, a horizontal line passing through O, the lowest point of the fall; for if O L were much less than nine inches, the water, having spent the greater part of its force in impelling the float-boards, would accumulate below the wheel and retard its motion. For the same reason, another course, which is called by M. Fabre the course of discharge, (le coursier de décharge,) should be connected with L M V by the curve V N, to preserve the remaining velocity of the water, which would otherwise be destroyed by falling perpendicular from V to N. The course of discharge is represented by V Z, sloping from the point O. It should be about 16 yards long, having an inch of declivity in every two yards. The canal, which reconducts the water from the course of discharge to the river, should slope about four inches in the first 200 yards, three inches in the second 200 yards, decreasing gradually till it terminates in the river. But if the river, to which the water is conveyed, should, when swollen by the rains, force the water back upon the wheel, the canal must have a greater declivity, in order to prevent this from taking place. Hence it will be evident that very accurate levelling is necessary for the proper formation of the mill-course.

ON SETTING OUT WATER-COURSES AND DAMS.

The most ancient mills were undershot-wheels placed in the current of an open river, the building containing the mill being set upon piles in the river. It would soon be observed that the power of the mill would be greatly increased if all the water of the river was concentrated to the wheel, by making an obstruction across the river which penned up the water to a required height; and also to form a pool or reservoir of water. A sluice or shuttle would then become necessary to regulate the admission of water to the wheel, and other sluices would be necessary to allow the water to escape in times of floods; for though in ordinary times the water would run over the top of the obstruction or dam, yet a very great body of water running over might carry away the whole work, by washing away the earth at the foot of the dam, and then overturning it into the excavation. This is an accident which frequently happens to mills so situated; and the danger is so obvious, that most water-mills are now removed to the side of the river, and a channel is dug from the river to the mill to supply it with water, and another to return the water from the mill to the river. The difference of level between these two channels is the fall of water to work the mill, and this is kept up by means of a wear or dam entirely across the river, but the water can run freely over this dam in case of floods, without at all affecting the mill, because the entrance to the channel of supply is regulated by sluices and side-walls.

The dam should be erected across the river at a broad part, where it will pen up the water so as to form a large pond or reservoir, which is called the mill-pond or dam-head. This reservoir is useful to gather the water which comes down the river in the night, and reserve it for the next day's consumption; or for such mills as do not work incessantly, but which require more water, when they do work, than the ordinary stream of the river can supply in the same time. The larger the surface of the pond is, the more efficient it will be, but depth will not compensate for the want of surface, because, as the surface sinks, when the water is drawn off, the fall or descent of the water, and consequently the power of the water, diminishes.

The dam for a large river should be constructed with the utmost solidity; wood framing is very commonly used, but masonry is preferable. Great care must be taken, by driving pile planking under the dam, to intercept all leakage of the water beneath the ground under the dam, as that loosens the earth, and destroys the foundation imperceptibly, when a violent flood may overthrow the whole. It is a common practice to place the dam obliquely across the river, with a view of obtaining a greater length of wall for the water to run over, and consequently prevent its rising to so great a height, in order to give vent to the water of a flood. But this is very objectionable, because the current of water constantly running over the dam, always acts upon the shore or bank of the river at one point, and will in time wear it away, if not prevented by expensive works. This difficulty is obviated by making the dam in two lengths which meet in an angle >, the vertex pointing up the stream. In this way the currents of water, coming from the two opposite parts of the dam, strike together, and spend their force upon each other, without injuring any part. A still better form is a segment of a circle, which has the additional advantage of strength, because if the abutments at the banks of the river are firm, the whole dam becomes like the arch of a bridge laid down horizontally. This was the form generally used by Mr Smeaton.

The foot of the dam where the water runs down should be a regular slope with a curve, so as to lead the water down regularly; and this part should be evenly paved with stone, or planked, to prevent the water from tearing it up when it moves with a great velocity.

When the fall is considerable, it may be divided into more than one dam; and if the lower dam is made to pen the water upon the foot of the higher dam, then the water running over the higher dam, will strike into the water, and lose its force. There is nothing can so soon exhaust the force of rapid currents of water, as to fall into other water, because its mechanical force is expended in changing the figure of the water; but when it falls upon stone or wood, its force is not taken away, but only reflected to some other part of the channel, and may be made to act upon such a great extent of surface as to do no very striking injury at any one time; but by degrees it wears away the banks, and requires constant repairs: for it is demonstrable, that, as much of the force of the water as is not carried away by the rapid motion with which it flows, after passing the dam, must be expended either in changing the figure of the water, or in washing away the banks, or in the friction of the water running over the bottom.

The cotton-works of Messrs Strutt, at Belper, in Derbyshire, are on a large scale, and the most complete we have ever seen, in their dams and water-works. The mills are turned by the water of the river Derwent, which is very subject to floods. The great wear is a semicircle, built of very substantial masonry, and provided with a pool of water below it, into which the water falls. On one side of the wear are three sluices, each 20 feet wide, which are drawn up in floods, and allow the water to pass sideways into the same pool; and on the opposite side is another such sluice, 22 feet wide. The water is retained in the lower pool by some obstruction which it experiences in running beneath the arches of a bridge; but the principal fall of the water is broken by falling into the water of the pool, beneath the great semicircular wear.

The water which is drawn off from the mill-dam above the wear, passes through three sluices, 20 feet wide each, and is then distributed by different channels to the mills, which are situated at the side of the river, and quite secure from all floods. There are six large water-wheels; one of them, which is 40 feet in breadth, we have mentioned, from the ingenuity of its construction; and another, which is made in two breadths of 15 feet each, we have also described. They are all breast-wheels. The iron-works of Messrs Walker, at Rotherham, in Yorkshire, are very good specimens of water-works; as also the Carron-works in Scotland.—Dr Rees's *Cyclopædia* and Dr Brewster's *Ferguson*.

PENSTOCK.

The following is a description of a pentrough and stock for equalizing the water falling on water-wheels, by Mr Quayle.

To ensure a regular supply of water on the wheel, and to obviate the inconveniences arising from the usual mode of delivering it from the bottom of the pentrough, this method is devised of regulating the quantity delivered by a float, and taking the whole of the water from the surface.

Section of the pentrough. Fig. 99. A, the entrance of the water; B, the float, having a circular aperture in the centre, in which is suspended C, a cylinder, running down in the case E below the bottom of the pentrough. This is made water-tight at the bottom of the pentrough at F, by a leather collar placed between two plates, and screwed down to the bottom. The cylinder is secured to the float so as to follow its rise and fall; and the water is admitted into it through the opening in its sides, and there, passing through the box or case E, rises and issues at G on the wheel. By this means, a uniform quantity of water is obtained at G; which quantity can be increased or diminished by the assistance of a small rack and pinion attached to the cylinder, which will raise or depress the cylinder above or under the water line of the float; and, by raising it up to the top, it stops the water entirely, and answers the purpose of the common shuttle. This pinion is turned by the handle H, similar to a winch-handle; and is secured from running down by a ratchet-wheel at the opposite end of the pinion axis.

K and L are two upright rods to preserve the perpendicular rise and sinking of the float, running through the float, and secured at the top by brackets from the sides.

M, a board let down across the pentrough nearly to the bottom, to prevent the horizontal impulse of the water from disturbing the float.

Fig. 99*. A transverse section, showing the mode of fixing the rack and pinion, and their supports on the float. The rack is inserted into a piece of metal running across the cylinder near the top. That the water may pass more freely when nearly exhausted, the bottom of the cylinder is not a plane, but is cut away so as to leave two feet, as at C, fig. 99. The float is also kept from lying on the pentrough bottom by four small feet; so that the water gets under it regularly from the first.

Fig. 99**. An enlarged view of the cylinder, showing the rack and ratchet-wheel, with the clink and one of the openings on the side of the cylinder; the winch or handle being on the opposite side, and the pinion, by which the rack is raised, enclosed in a box between them.

MR SMEATON'S PENTROUGH.

Fig. 93*. G represents the pentrough through which the water flows, and F F strong cross beams on which it is supported; the wheel is situated very close beneath the bottom of the trough, as the figure shows. E E are two arms of the wheel, which are put together, as shown in fig. 110. B D is the wooden rim of the wheel; the narrow circle beyond this is the section of the sole planking, and on the outside of this the bucket-boards are fixed as the figure shows; one of the bottom-boards, *b*, of the trough at the end is inclined, and an opening is left between that end and the other boards of the bottom to let the water pass through; this opening is closed by a sliding shuttle *c*, which is fitted to the bottom of the trough, and can be moved backwards and forwards by a rod *d*, and lever *e*, which is fixed into a strong axis *f*; this axis has a long lever on the end, which, being moved by the miller, draws the shuttle along the bottom of the trough, and increases or diminishes the aperture through which the water issues. The extreme edge of the shuttle is cut inclined, to make it correspond with the inclined part *b*, and by this means it opens a parallel passage for the water to run through, and this causes the water to be delivered in a regular and even sheet; and to contribute to this the edges of the aperture where the water quits it are rendered sharp by iron plates; the shuttle is made tight where it lies upon the bottom of the trough, by leather, so as to avoid any leakage when the shuttle is closed. When the wheel is of considerable breadth, the weight of the water might bend down the middle of the trough until it touched the wheel; to prevent this, a strong beam, O, is placed across the trough, and the trough is suspended from this by iron bolts which pass through grooves in the shuttle, so that they do not interfere with the motion of the shuttle.

Mr Nouaille took out a patent, in October, 1812, for a new method of laying water upon an overshot-wheel, (see fig. 94,) which he thus describes:—"In my new method of applying water to water-wheels, I cause it to commence its action upon a point of the wheel's circumference, which is about 53 degrees distant from the vertex, or the highest point thereof, instead of applying it at the top of the wheel, as heretofore commonly practised for overshot-wheels. By these means I can have the advantages of a large wheel in situations where the fall would only allow of a smaller, if the water was applied at the top; thus, if there be a perpendicular of 12 feet, I cause a wheel of 15 feet diameter to be made, and of course the water must be made to act upon it at a height of 12 feet, which is three feet perpendicular below the top of the wheel, and at about 53 degrees from the top, measured round its circumference as above stated. I make the pentrough which brings the water to the wheel of such a form that it delivers the water from the bottom of it though the floor, and is directed at such an angle as to fall into the buckets nearly in the direction of the wheel's motion, which will be at an angle of 75 degrees with the horizon; the shuttle or gate slides upon the floor of the trough, so as to cover the aperture, and determine the quantity of water to be let out upon the wheel.

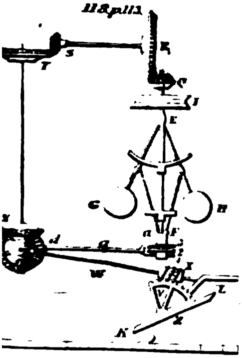
"The exact manner of carrying this principle into effect is particularly explained by the annexed draft, which is a vertical section of a water-wheel on my improved plan. In this the dotted line A A, fig. 116, represents the level of the water at its full head, and B the level of the tail-water: therefore A B is the extreme fall, A C is the depth of the water in the pentrough. Now instead of the common practice of making a wheel of the diameter equal to B C, I make the wheel D E F G one-fourth larger than B C, then the water will be delivered upon it at the point E. The floor C of the pentrough C H L, does not come up to meet the end H thereof, but leaves a small space through which the water issues in the dirèction of the dotted line I I, to the buckets of the wheel. The breadth of this space is determined by the shuttle K, which lays flat upon the floor of the pentrough, and slides over the aperture. It is regulated by means of a lever N, acted upon by a screw, rack, or other adjustment, at M, and the water is thus delivered in a very thin and regular sheet into the buckets."

Fig. 117 represents a method of laying on water which has for several years been in common use in Yorkshire and the north of England. In this the water is not applied quite at the top of the wheel, but nearly in the same position as the last described; but the advantages of this wheel over all others is, that the water can be delivered at a greater or less height, according to the height at which the water stands in the trough; but in all the preceding methods, if the water is subject to variations of height, as all rivers are, then the wheel must be diminished, so that in the lowest state of the water it will stand a sufficient depth above the orifice in the bottom of the trough to issue with a velocity rather greater than the motion of the wheel. In this case, when the water rises to its usual height, or above it, the increase of fall thus obtained is very little advantage to the wheel; the improved wheel can at all times take the utmost fall of the water, even when its height varies from three to four feet. A A is the pentrough made of cast-iron; the end of it is formed by a grating of broad flat iron bars, which are inclined in the proper position to direct the water through them into the buckets of the wheel. The spaces between the bars are shut up by a large sheet of leather, which is made fast to the bottom of the iron trough at *a*, and is applied against the bars; and the pressure of the water keeps it in close contact with the bars, so as to prevent any leakage. This is the real shuttle, and to open it so as to give the required stream

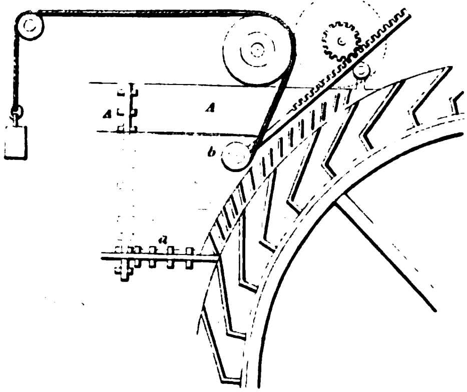
WATER WHEELS.

From 109 to 121

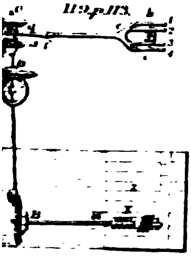
118.p.113.



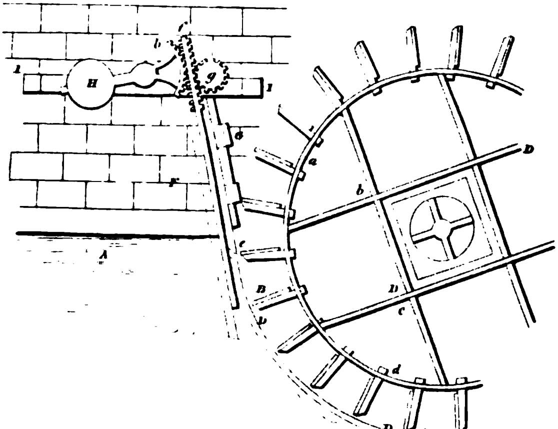
117.p.112.



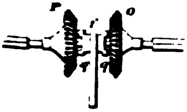
119.p.113.



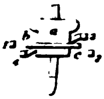
110.p.89.



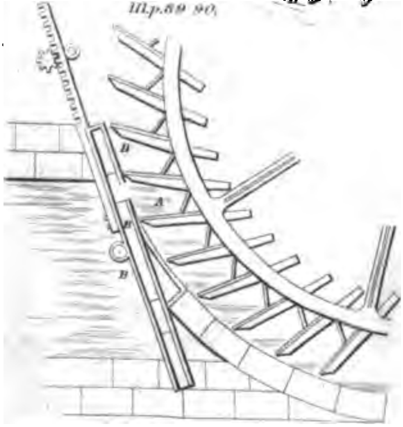
120.p.113



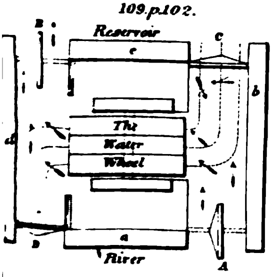
121.p.113.



111.p.89 90.



109.p.102.



of water to the wheel, the upper edge of the leather is wrapped round a smaller roller, *b;* the pivots at the ends of this roller are received in the lower ends of two racks, which are made to slide up and down by the action of two pinions fixed upon a common axis which extends across the trough; this axis being turned, raises up or lowers down the roller, and the leather shuttle winds upon it as it descends, or unwinds from it as it ascends, so as to open more of the spaces between the bars or close them, as it is required. In order to make the roller take up the leather, and always draw it tight, a strap of leather is wound round the extreme ends of the rollers, beyond the part where the leather shuttle rolls upon it. These straps are carried above water and applied on wheels, which wind them up with a very considerable tension, by the action of a band and weight wrapped on the circumference of a wheel, which is on the end of the axis of those wheels.

The water runs over the upper side of the roller, and flows through the spaces between the grating into the buckets of the wheel; the descent of the water passing through the bars, and afterwards in falling before it strikes the bottom of the bucket, is found fully sufficient to produce the necessary velocity of the water, for a fall of four inches produces a velocity of more than four feet per second.

We recommend this as the best method of applying the water, as we see in all other forms that a much greater portion of the fall is given up in order to make the water flow into the wheel; not that any such depth as is commonly given is at all necessary, but the aperture in the trough must be placed so low that the water will run through it in the very lowest states of the water, otherwise the wheel must stop at such times.—Dr Rees's *Cyclopædia*. *Repertory of Arts*, 1813.

SLUICE GOVERNOR FOR REGULATING THE INTRODUCTION OF WATER UPON WATER-WHEELS OF ALL KINDS.

The ingenious Mr Burns actually constructed for the Cartside Cotton Mills, the sluice governor, represented at figs. 118, 119, 120, and 121, which was considered of such advantage as to produce a saving of more than 100*l.* per annum.

The motion of the water-wheel is communicated by a belt or rope going round the pulley I to the axis E F, which carries the balls G H, fig. 118. This motion is conveyed to the upright shaft T, by the wheels and pinions Q, R, S, T, and the wheel N at the bottom of the shaft drives the wheels

O, P, figs. 119 and 120, in opposite directions. When the velocity of the wheel is such as is required, the wheels O, P, move loosely about the axis, and carry the motion no farther. But when the velocity of the wheel is too great, the balls G, H, separated by the increase of centrifugal force, raise the box *a* upon the shaft E F. An iron cross *b c*, see fig. 121, is fitted into the box *a*. This cross works in the four prongs of the fork *e b c*, fig. 119, at the end of the lever *d q f e*, which moves horizontally round *f* as its centre of motion. When the box *a* is stationary, which is when the wheel has its proper velocity, the iron cross works within two of the prongs so as not to affect the lever *a f c*, but to allow the clutch *q q*, fixed at the end of the lever, to be disengaged from the wheels. When the cross *b c* rises, it strikes in turning round the prong 3, see fig. 121, which drives aside the lever *e f a*, and throws the clutch *q* into the arms of the wheel P, figs. 119, 120. This causes it to drive round the shaft D C in one direction. When the iron cross *b c*, on the contrary, is depressed by any diminution in the velocity of the wheel, it strikes in turning round the prong 4, which pushes aside the lever *e f d*, and throws the clutch *q* into the wheel O. This causes the wheel O to drive the shaft in an opposite direction to that in which it was driven by P. Now the shaft D C, which is thus put in motion, drives, by means of the pinion C and wheel B, the inclined shaft B W, which, by an endless screw, X, working in the toothed quadrant Z, elevates or depresses the sluice K L, and admits a greater or a less quantity of water, according to the motion given to the shaft by the wheel P or O. This change in the aperture is produced very gradually, as the train of wheel-work is made so as to reduce the motion at the sluice. The centre in which the sluice turns should be one-third of its height from the bottom, in order that the pressure of the water on the part above the centre may balance the pressure on the part below the centre.

MR FERGUSON'S RULES FOR THE CONSTRUCTION OF UNDERSHOT WATER-MILLS.

When the float-boards of the water-wheel move with a third part of the velocity of the water that acts upon them, the water has the greatest power to turn the mill: and when the mill-stone makes about 60 revolutions in a minute, it is found to do its work the best. For, when it makes but about 40 or 50 it grinds too slowly, and when it makes more than 70, it heats the meal too much, and cuts the bran so small, that a great part thereof mixes with the meal, and cannot be separated from it by sifting or boulting. Consequently, the utmost perfection of mill-work lies in making the train so, as that the mill-stone shall make about 60 turns in a minute when the water-wheel moves with a third part of the velocity of the water. To have it so, observe the following rules:

1. Measure the perpendicular height of the fall of water, in feet, above the middle of the aperture, where it is let out to act by impulse against the float-boards on the lowest side of the undershot-wheel.

2. Multiply this constant number 64.2882, by the height of the fall in feet, and extract the square root of the product, which shall be the velocity of the water at the bottom of the fall, or the number of feet the water moves per second.

3. Divide the velocity of the water by 3, and the quotient shall be the velocity of the floats of the wheel, in feet, per second.

4. Divide the circumference of the wheel in feet, by the velocity of its floats, and the quotient will be the number of seconds in one turn or revolution of the great water-wheel on whose axis the cog-wheel that turns the trundle is fixed.

5. Divide 60 by the number of seconds in a turn of the water-wheel, or cog-wheel, and the quotient will be the number of turns of either of these wheels in a minute.

6. By this number of turns divide 60, (the number of turns the mill-stone ought to have in a minute,) and the quotient will be the number of turns the mill-stone ought to have for one turn of the water or cog-wheel. Then,

7. As the required number of turns of the mill-stone in a minute is to the number of turns of the cog-wheel in a minute, so must the number of cogs in the wheel be to the number of staves in the trundle on the axis of the mill-stone, in the nearest whole number that can be found. By these rules the following table is calculated; in which the diameter of the water-wheel is supposed to be 18 feet, (and consequently its circumference 56$\frac{4}{7}$ feet,) and the distance of the mill-stone to be five feet.

Perpendicular height of the fall of water in feet.	Velocity of the water, in feet, per second.	Velocity of the wheel, in feet, per second.	Number of turns of the wheel in a minute.	Required number of turns of the mill-stones for each turn of the wheel.	Nearest number of cogs and staves for that purpose.		Number of turns of the mill-stone for one turn of the wheel by these cogs and staves.	Number of turns of the mill-stone in a minute by these cogs and staves.
					Cogs.	Staves.		
1	8.02	2,67	2.63	21.20	127	6	21.17	59.91
2	11.40	3.72	4.00	15.00	105	7	15.00	60.00
3	13.89	4.63	4.91	12.22	98	8	12.25	60.14
4	16.04	5.35	5.67	10.58	95	9	10.56	59.87
5	17.93	5.98	6.34	9,46	85	9	9.44	59.84
6	19.64	6.55	6.94	8.64	78	9	8.66	60.10
7	21.21	7.07	7.50	8.00	72	9	8.00	60.00
8	22.68	7.56	8.02	7.48	67	9	7.44	59.67
9	24.05	8.02	8.51	7.05	70	10	7.00	59.57
10	25.35	8.45	8.97	6.69	67	10	6.70	60.09
11	26.59	8.86	9.40	6.38	64	10	6.40	60.16
12	27.77	9.26	9.82	6.11	61	10	6.10	69.90
13	28.91	9.64	10.22	5.87	59	10	5.90	60.18
14	30.00	10.00	10.60	5.66	56	10	5.60	59.36
15	31.05	10.35	10.99	5.46	55	10	5.40	50.48
16	32:07	10.69	11.34	5.29	53	10	5.30	60.10
17	33.06	11.02	11.70	5.13	51	10	5.10	59.67
18	34.12	11.34	12.02	4.90	50	10	5.00	60.10
19	34.95	11.65	12.37	4.85	49	10	4.80	60.61
20	35.86	11.92	12.68	4.73	47	10	4.70	59.59
1	2	3	4	5	6		7	8

Example.—Suppose an undershot-mill is to be built where the perpendicular height of the fall of water is nine feet; it is required to find how many cogs must be in the wheel, and how many staves in the trundle, to make the mill-stone go about 60 times round in a minute, while water-wheel floats move with a third part of the velocity with which the water spouts against them from the aperture at the bottom of the fall.

Find 9, (the height of the fall,) in the first column of the table; then against that number in the sixth column, is 70 for the number of cogs in the wheel, and 10 for the number of staves in the trundle; and by these numbers we find in the eighth column that the mill-stone will make $59\frac{57}{100}$ turns in a minute, which is within half a turn of 60, and near enough for the purpose; as it is not absolutely requisite that there should be just 60 without any fraction: and throughout the whole table the number of turns is not quite one more or less than 60.

The diameter of the wheel being 18 feet, and the fall of water nine feet, the second column shows the velocity of the water at the bottom of the fall to be $24\frac{5}{100}$ feet per second; the third column the velocity of the float-boards of the wheel to be $8\frac{2}{100}$ feet per second; the fourth column shows that the wheel will make $8\frac{52}{100}$ turns in a minute; and the sixth column shows that for the mill-stone to make exactly 60 turns in a minute, it ought to make $7\frac{5}{100}$, (or seven turns and one-twentieth part of a turn,) for one turn of the wheel.

Dr Brewster, in the valuable Appendix which he has annexed to his edition of Mr Ferguson's works, shows, that the principles upon which the above table is calculated, are erroneous, owing to the author having, with Desagulier and Maclaurin, embraced M. Parent's theory, which Mr Smeaton, by repeated experiments, proved to be incorrect.

The constant number used by Mr Ferguson for finding the velocity of the water from the height of the fall, 64.2882, appears to be also wrong. For, from some recent experiments made by Mr Whitehurst on pendulums, it is found that a heavy body falls 16.087 feet in a second of time: consequently the constant number should be 64.348.

Dr Brewster then states, that in Mr Ferguson's table the velocity of the mill-stone is too small; and Mr Imison, in correcting this mistake, has made the velocity too great. From this circumstance, the Mill-wrights' Table, as hitherto published, is fundamentally erroneous, and is more calculated to mislead than to direct the practical mechanic. Proceeding, therefore, upon the practical deductions of Smeaton, as confirmed by theory, and employing a more correct constant number, and a more suitable velocity for the mill-stone, we may construct a new Mill-wrights' Table by the following rules:

1. Find the perpendicular height of the fall of water in feet above the bottom of the mill-course, at K, (fig. 100,) and having diminished this number by one-half of the natural depth of the water at K, call that the height of the fall.

2. Since bodies acquire a velocity of 32.174 feet in a second, by falling through 16.087 feet, and since the velocities

of falling bodies are as the square roots of the heights through which they fall, the square root of 16.087 will be to the square roots of the height of the fall, as 32.174 to a fourth number, which will be the velocity of the water. Therefore the velocity of the water may be always found by multiplying 32.174 by the square root of the height of the fall, and dividing that product by the square root of 16.087. Or it may be found more easily by multiplying the height of the fall by the constant number 64.348, and extracting the square root of the product, which, abstracting the effects of friction, will be the velocity of the water required.

3. Take *one-half* of the velocity of the water, and it will be the velocity which must be given to the float-boards, or the number of feet they must move through in a second, in order that the greatest effect may be produced.

4. Divide the circumference of the wheel by the velocity of its float-boards per second, and the quotient will be the number of seconds in which the wheel revolves.

5. Divide 60 by this last number, and the quotient will be the number of revolutions which the wheel performs in a minute. Or the number of revolutions performed by the wheel in a minute, may be found by multiplying the velocity of the float-boards by 60, and dividing the product by the circumference of the wheel, which in the present case is 47.12.

6. Divide 90, (the number of revolutions which a mill-stone five feet diameter should perform in a minute,) by the number of revolutions made by the wheel in a minute, and the quotient will be the number of turns which the mill-stone ought to make for one revolution of the wheel.

7. Then, as the number of revolutions of the wheel in a minute is to the number of the revolutions of the mill-stones in a minute, so must the number of staves in the trundle be to the number of teeth in the wheel, in the nearest whole numbers that can be found.

8. Multiply the number of revolutions performed by the wheel in a minute, by the number of revolutions made by the mill-stone for one of the wheel, and the product will be the number of revolutions performed by the mill-stone in a minute.

In this manner the following table has been calculated for a water-wheel 15 feet in diameter, which is a good medium size, the mill-stone being five feet in diameter, and revolving 90 times in a minute.

DR BREWSTER'S MILL-WRIGHT'S TABLE.

In which the velocity of the wheel is three-sevenths of the velocity of the water, and the effects of friction on the velocity of the stream reduced to computation.

Height of the fall of water.	Velocity of the water per second, friction being considered.	Velocity of the wheel per second, being 3-7ths that of the water.	Revolutions of the wheel per minute, its diameter being 15 feet.	Revolutions for mill-stone, for one of the wheel.	Teeth in the wheel, and staves in the trundles.		Revolutions of the mill-stones per minute by these staves and teeth.
Feet.	Feet. 100 parts of a foot	Feet. 100 parts of a foot.	Rev. 100 parts of a Rev.	Rev. 100 parts of a Rev.	Teeth.	Staves.	Rev. 100 parts of a Rev.
1	7.62	3.27	4.16	21.63	130	6	89.98
2	10.77	4.62	5.88	15.31	92	6	90.02
3	13.20	5.66	7.20	12.50	100	8	90.00
4	15.24	6.53	8.32	10.81	97	9	89.94
5	17.04	7.30	9.28	9.70	97	10	90.02
6	18.67	8.00	10.19	8.83	97	11	89.98
7	20.15	8.64	10.99	8.19	90	11	90.01
8	21.56	9.24	11.76	7.65	84	11	89.96
9	22.86	9.80	12.47	7.22	72	10	90.03
10	24.10	10.33	13.15	6.84	82	12	89.95
11	25.27	10.83	13.79	6.53	85	13	90.05
12	26.40	11.31	14.40	6.25	72	12	90.00
13	27.47	11.77	14.99	6.00	72	12	89.94
14	28.51	12.22	15.56	5.78	75	13	89.94
15	29.52	12.65	16.13	5.58	67	12	90.01
16	30.48	13.06	16.63	5.41	65	12	89.97
17	31.42	13.46	17.14	5.25	63	12	89.99
18	32.33	13.86	17.65	5.10	61	12	90.01
19	33.22	14.24	18.13	4.96	64	13	89.92
20	34.17	14.64	18.64	4.83	58	12	89.84
1	2	3	4	5	6		7

TREATISES ON MILL-WORK.

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WINDMILLS.

The windmill derives its name from the motion it receives from the impulse of the wind.

The date of its invention is not precisely known, though authors generally concur in believing it to have taken place at no very distant period of time. Some state it to have been first used in France in the sixth century: others, on the contrary, assert, that at the time of the crusades it was introduced into Europe from the east, where scarcity of water gave the impetus that led to its discovery.

Windmills are of two kinds, horizontal and vertical.

THE VERTICAL WINDMILL

Consists of a strong shaft, or axis, inclining a little upwards from the horizon, with four long yards, or arms, fixed to the highest end, perpendicular to the shaft, and crossing each other at right angles. Into these arms are mortised several small cross-bars, and to them are fastened two, three, or four, long bars, running in a direction parallel with the length of the arms; so that the bars intersect each other, and form a kind of lattice work, on which a cloth is spread to receive the action of wind. These are called the sails, and are in the shape of a trapezium, usually about nine yards long and two wide.

As the direction of the wind is very uncertain, and perpetually changing, it becomes necessary to have some contrivance for bringing the windshaft and sails into a position proper for receiving its impression. To effect this, two methods are in general use: the one called the post-mill; the other the smock-mill.

POST-MILLS.

In the post-mill it is accomplished by driving perpendicularly into the earth the trunk of a strong tree, that is held securely upright by several oblique braces, which extend from a platform on the ground to the middle of the tree, leaving 10 or 12 feet of the upper part free from the braces. The part thus left free from obstruction is rounded, and made to pass through a circular collar, formed in the flooring of the lower chamber, and to enter into a socket fixed into the flooring of the upper chamber, and to one of the strongest cross-beams, which must sustain the whole weight of the mill-house, so that, by means of a pivot, or gudgeon, fastened on that part of the post which enters into the socket, the whole machine can turn about horizontally to face the wind. A strong framing, united by joints to the back part of the mill-house, descends in a sloping direction till it touches the ground: the bottom of it is very heavy, and is fastened by cords to some short posts that are driven in a circle, at regular intervals round the mill, to prevent the mill from turning about at every sudden squall. This framing is furnished with steps to serve as a ladder of ascent or descent. At the bottom of it a rope is fastened, and carried thence in an inclined position to the top of the mill, where, by a lever or tackle of pullies, it can be shortened so as to raise the framing from the ground, and then by pushing against it in the manner of a lever, the whole mill may be turned in any required direction. To obtain more force, a small capstan is often provided to draw a rope fixed to the end of the ladder: this capstan is movable, and can be fastened at pleasure to any one of the posts.

The internal mechanism of a post-mill is exhibited in fig. 123. W X Y the upper chamber; X Y Z the lower one; A B the shaft, or axis, with the cog-wheel G, moving round in order of the letters that describe the sails C D E F, giving motion to the lantern H, and its spindle I K; L M is a bridge to support the said spindle; and N and O P are beams to sustain the bridge. The top mill-stone Q is the only one that moves, and is fixed on the spindle I K by a piece of iron, called the rynd, let in at the lower part of the stone; the lower mill-stone R, is somewhat larger than the other. The corn is put into the hopper S, and runs from thence along the spout T; the spindle I K, being square, shakes in its revolutions the spout T, and causes the corn to fall through the hole V between the stones, where it is ground; the flour then passes through the tunnel *a b*, and is finally deposited in the chest *c; d e* is a string going round the pin *d*, and serving to draw the spout T nearer to, or farther from, the spindle I K, that the corn may be made to run out either faster or slower, according to the velocity of the wind; *f g* and *h i* are levers, whose centres of motion are *f* and *m; i l n p* is a cord going about the pins *l* and *n* to wind up and raise the stone Q. By bearing down the end *r h*, *g* is raised, which raises the perpendicular N O, the perpendicular raises the cross-beam O P, the cross-beam the bridge L M and the spindle I K, together with the upper mill-stone Q, so that the stones can be set at any required distance apart. The corn is drawn up to the top of the mill by means of a rope rolled about the axis A B; *q r* is a ladder for ascending to the higher part of the mill. A girt or gripe of pliable wood is fixed at one end *s*, and at the other tied to the lever *t v*, movable about at *w*, which being pressed down stops the motion of the mill at pleasure. When the wind is great, the sails are only in part, or on one side covered, and sometimes only one half of two opposite sails. The same shaft can have another cog-wheel fixed to the end B, with trundle and mill-stones similar to those already described: by which means the shaft can turn two pair of stones at once; and when one pair only is wanted to grind, the lantern H and spindle I K are taken out from the other.

SMOCK-MILL.

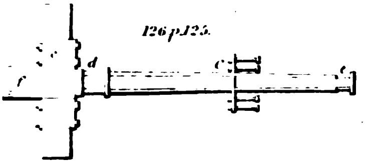
The other method of bringing the windshaft and sails into a position proper for receiving the impression of the wind is, by what is called the smock-mill. This mill is more expensive in the construction, and more decidedly advantageous, as it can be made of any required dimensions. It is built in the form of a round turret, having at the top of it a wooden ring with a groove in it, furnished with a number of brass truckles, kept equi-distant from each other by their centre pins being fixed into a circular hoop. Into this groove the framing of the upper or movable part of the mill, which is called the head, or cap, enters, and a very slight power is alone sufficient to turn it about that the sails may receive the action of the wind. The head or cap is very ingeniously contrived to turn itself about whenever the wind changes, by a small pair of sails, or fans, fixed up in a frame that projects from the back part of the head.

Fig. 124, *a* the fans, having on its axis a pinion of 10 leaves *b*, which gives motion to a cog-wheel of 60 teeth *c*, its axis *d*, and a pinion of 12 teeth at the lower end *e*, turning a bevelled wheel of 72 teeth *f*, a vertical iron shaft *g*, having a pinion of 11 teeth *h*, that works in a circle of 120 cogs. Therefore, whenever the wind changes, it acts obliquely upon the vanes of the fan, and turns it round, which, giving an impulse to the connecting machinery, brings the main shaft of the sails slowly about to face the direction of the wind. The method of this operation is as follows: the fans, having received the action of the wind, turn round, and the pinion *b*, of 10 leaves, that is upon its axis, gives motion to the cog-wheel of 60 teeth *c*, fixed on an inclined axis which has at the lower end the pinion of 12 leaves *e*, acting upon the bevelled wheel of 72 teeth *f*, fixed on a vertical iron axis, and giving motion to the pinion of 11 teeth *h*, that works in the circle of 120 cogs. A B two of the sails, (the other two being endwise cannot be seen,) fixed on an iron shaft or axis C D, by screwing them to an iron cross formed at one end of it. Upon this shaft is the cog-wheel E, that acts upon the lantern F, fixed on a strong vertical shaft extending from the top to the bottom of the mill, and having on the lower end the large wheel *i i*, giving motion to the two opposite pinions *k k*, which turn the spindles and the mill-stones G H. A wheel is fixed on the main axis at I, to give action to the pinion on the horizontal roller *m*, which has a rope wrapped about it to wind up the sacks of corn. The same wheel I turns another horizontal axis that has several wheels, to receive endless ropes for turning the bolting and dressing machines. On the middle part of the vertical shaft K L is the wheel I, which turns the roller *m*, to draw up the sacks of corn from the lower part of the mill, which is used as a storehouse; being divided into as many compartments as the miller may require. To the mill-stone spindle is attached a pair of regulating balls, to regulate the velocity of the mill. For the manner of applying this regulator see fig. 125, *l* a spindle, on which is fixed the pinion *k*, playing into the large wheel that is attached to the vertical shaft; the lower end of the spindle enters into a square formed on the top of the mill-stone axis at *m*; immediately beneath the pinion two iron rods are jointed, bending downwards, having a heavy iron ball *o o* fastened to the end of each; to these rods are attached two links at *p p*, to suspend a collar capable of sliding freely up and down upon the spindle *l*; this collar is embraced by a fork, formed on a steelyard, lying horizontal, and suspended by the fulcrum *q*; *r* is an iron rod fixed at the extreme end of the steelyard, and having at the bottom an

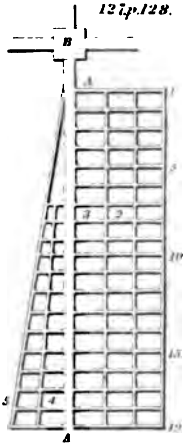
WINDMILLS.

From 123 to 129

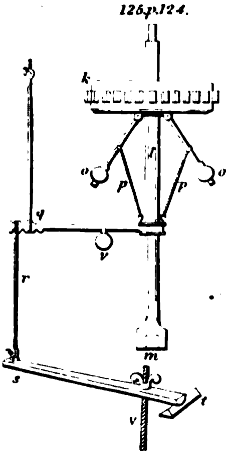
126 p.125.



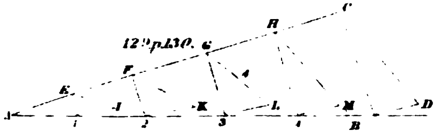
127 p.128.



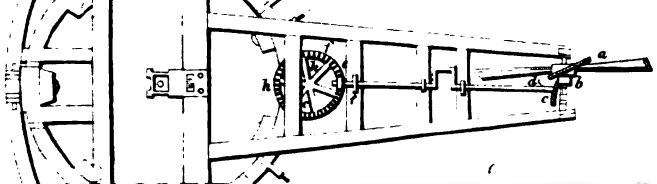
125 p.124.



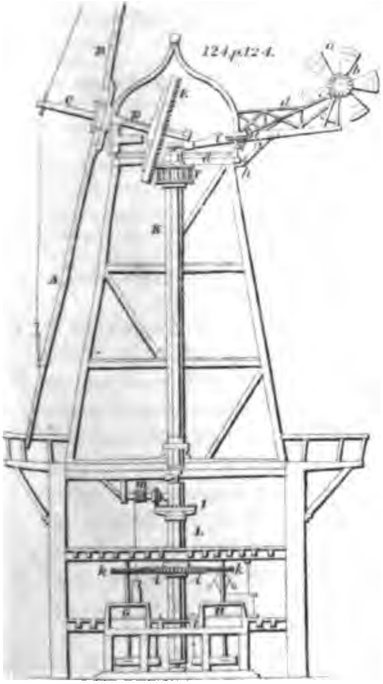
129 p.130.



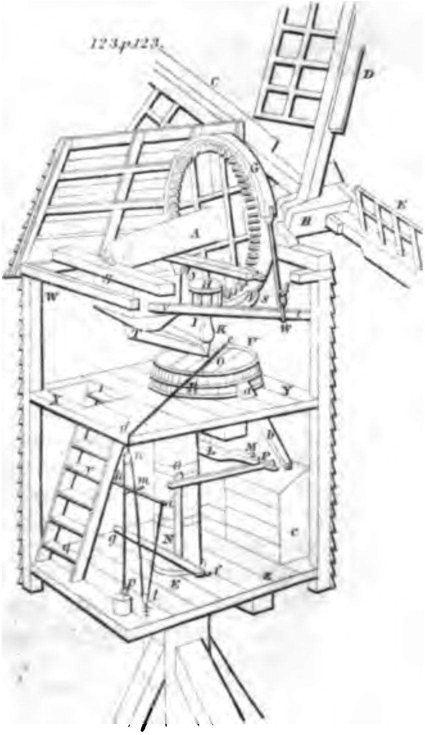
124 p.124.



124 p.124.



123 p.123.



iron hook to connect it with the lever *s*, whose fulcrum is *t*; this, by means of an iron rod, suspends one end of the bridge on which the lower pivot of the mill-stone rests, the other end bearing on a fulcrum, or centre.

Whenever the mill acquires velocity, the iron balls, by their centrifugal force, will fly out, and elevate the collar, which, acting upon the connecting parts, will let the upper mill-stone down nearer to the lower one, and the resistance or friction thus caused will counteract the increased velocity of the wind. On the contrary, if the wind decreases, the balls will fall towards each other, and let down the sliding collar, which will raise the top mill-stone, and by increasing the distance between it and the lower one, cause the mill to acquire greater velocity. For this purpose a weight *v* is hung upon the steelyard, sufficient to raise the stone whenever the descent of the collar will permit it so to do. Several notches are cut into the steelyard for different positions of the fulcrum *q* and rod *r*, to regulate more effectually the motion of the machinery. For instance, if the wind should blow stronger, and the mill go slower, contrary to the effect expected, it shows that the regulation is too strong : to remedy this, the leverage of the balls must be increased by reducing the distance between the fulcrum *q* and the rod *r*, by shifting either of them into different notches. On the other hand, if the velocity of the mill should increase with the velocity of the wind, it shows that the regulation is not strong enough, and that the fulcrum *q* and the rod *r* must be set a greater distance apart. Sometimes it happens that the whole limits of the notches on the steelyard is insufficient to effectuate the desired object ; in such case, the acting length of the lever *s s* must be increased or diminished by removing the fulcrum *t* to a greater or less distance from the suspended rod *v*.

In fig. 126 is shown the construction of the horizontal shaft or axis that bears the sails. It is an octagonal iron shaft, having two cylindrical necks, *e* and *d*, where it rests upon its bearings. At the end it has a kind of box which has two mortises, *e* and *f*, through it in perpendicular directions, to receive the sails. At the back of one of these mortises, and the front of the other, a projecting arm is left in the casting to receive screw bolts for holding the sails secure in the mortises. The sails are braced to each arm by a rope stay, proceeding from the end of a pole, fixed at the end of the cast-iron axis. Each sail is formed of a sail cloth, spread upon a kind of lattice work, similar to that described under the head of Post-mill. The plane of this frame is inclined to the plane of the sail's motion, at such an angle, that the wind blowing in the direction of the axis acts upon the sails as inclined planes, and turns them about with a power proportionate to the size of the sails and the force of the wind. The cog-wheel is fixed on the axis, by bolting its arms against the stanch marked C. The mill-stones are the same as those described under the head of Flour-mill.

Parent, Euler, and other geometricians have written much upon the nature and construction of windmills ; but as we consider the experiments and researches made by our own countryman Smeaton to be far superior in point of practical utility, we shall content ourselves with giving his opinion as to the shape, magnitude, and position of the sails.

By Mr Smeaton's experiments it appears, that when the sails were set at the angle of 55 degrees with the axis, proposed as the best by M. Parent and others, they were the most disadvantageous of any that were tried by him.

On increasing the angle of the sails with the axis from 72 to 75 degrees, an augmentation of power was produced in the ratio of 31 to 45, and this proves to be the angle most commonly in use when the surfaces of the sails are planes.

If nothing more were requisite than to make the mill acquire motion from a state of rest, or to prevent it from passing into rest from a state of motion, the position recommended by M. Parent would be the best; but if the sails are intended, with given directions, to produce the greatest effect possible in a given time, we must reject M. Parent's position; and, if use be made of planes, confine our angle within the limits of 72 and 75 degrees with the axis.

The variation of a degree or two in the angle makes very little difference in the effect, when the angle is near upon the best.

Mr Smeaton made several experiments upon a large scale, and found the following angles to answer as well as any. The radius is supposed to be divided into six parts, and one-sixth, reckoning from the centre, is called one, the extremity being denoted six.

No.	Angle with the axis.	Angle with the plane of the motion.
1	72°	18
2	71	19
3	72	18 middle
4	74	16
5	77½	12½
6	83	7 extremity.

Having thus obtained the best position of the sails, or manner of weathering, as it is called by the workmen, Mr Smeaton next proceeded to try what advantage could be made by an addition of surface upon the same radius. The result was, that a broader sail requires a greater angle; and that when the sail is broader at the extremity than near the centre, this shape is more advantageous than that of a parallelogram. The figure and proportion of the enlarged sails he found to answer best upon a large scale, where the extreme bar is one-third of the radius, or whip, and is divided by the whip in the proportion of 3 to 5. The triangular, or leading sail, is covered with board, from the point downwards, one-third of its height, the rest with cloth as usual. The angles mentioned in the preceding article are found to be the best for the enlarged sails also; for in practice it is found, that the sails had better have too little than too much wind.

Many persons have imagined that the more sail the greater the advantage, and have therefore proposed to fill up the whole area, and by making each sail a sector of an ellipsis, according to M. Parent, to intercept the whole cylinder of wind, and thereby to produce the greatest effect possible: but from our author's experiments it appears, that when the surface of all the sails together exceeded seven-eighths of the circular area containing them, the effect was rather diminished than augmented; and consequently, he concludes, that when the whole cylinder of wind is intercepted, it does not then produce the greatest effect for want of proper interstices to escape.

"It is certainly desirable," says Mr Smeaton, "that the sails of windmills should be as short as possible, but at the same time it is equally desirable the quantity of cloth should be the least that may be, to avoid damage by sudden squalls of wind. The best structure, therefore, for large mills, is that where the quantity of cloth is the greatest in a given circle that can be: on this condition, that the effect holds out in proportion to the quantity of cloth; for otherwise the effect can be augmented in a given degree by a lesser increase of cloth upon a larger radius, than would be required if the cloth were increased upon the same radius."

The ratios between the velocities of windmill sails unloaded, and when loaded to their maximum, turned out different in different experiments, but the most general ratio of the whole was as 3 to 2. In general, however, it appeared, where the power was greater, whether by an enlargement of surface, or a greater velocity of the wind, that the second term of the ratio was less.

The ratio between the greatest load that the sails will bear without stopping, or what is nearly the same thing, between the least load that will stop the sails, and the load at the maximum, were confined between that of 10 to 8, and of 10 to 9; and at a medium about 10 to 8.3, or of 6 to 5; though it appeared on the whole, that where the angle of the sails or quantity of cloth was greatest, the second term of the ratio was less.

The following maxims have been deduced by Mr Smeaton from his experiments:

Maxim 1. The velocity of the windmill sails, whether unloaded or loaded, so as to produce a maximum, is nearly as the velocity of the wind, their shape and motion being the same.

Maxim 2. The load at the maximum is nearly, but somewhat less than, as the square of the velocity of the wind, the shape and position of the sails being the same.

Maxim 3. The effects of the same sails at a maximum are nearly, but somewhat less than, as the cubes of the velocity of the wind.

Maxim 4. The load of the same sails at the maximum is nearly as the squares, and their effects as the cubes of their number of turns in a given time.

Maxim 5. When the sails are loaded so as to produce a maximum at a given velocity, and the velocity of the wind increases the load containing the same: first, the increase of effect, when the increase of the velocity of the wind is smaller, will be nearly as the squares of those velocities; secondly, when the velocity of the wind is double, the effects will be nearly as 10 to 27⅓; but thirdly, when the velocities compared are more than double of that where the given load produces a maximum, the effects increase nearly in a simple ratio of the velocity of the wind.

Maxim 6. If sails are at a similar figure and position, the number of turns in a given time will be reciprocally as the radius or length of the sail.

Maxim 7. The load at a maximum that sails of a similar figure and position will overcome, at a given distance from the centre of motion, will be as the cube of the radius.

Maxim 8. The effect of sails of similar figure and position are as the square of the radius.

Maxim 9. The velocity of the extremity of Dutch sails, as well as of the enlarged sails, in all their usual positions when unloaded, or even loaded to a maximum, are considerably quicker than the velocity of the wind.

Mr Ferguson remarks, that it is almost incredible to think with what velocity the tips of the sails move when acted upon by a moderate wind. He several times counted the number of revolutions made by the sails in 10 or 15 minutes; and, from the length of the arms from tip to tip, has computed, that if an hoop of the same size were to run upon plain ground with equal velocity, it would go upwards of 30 miles in an hour.

RULES FOR MODELLING THE SAILS OF WINDMILLS.

Fig. 127 is a front view of one of the four sails of a windmill. The letters of reference will serve to explain the terms made use of in the following description:

1. The length of the arm, or whip A A, reckoned from the centre of the great shaft B to the outermost bar 19, governs all the rest.
2. The breadth of the face of the whip A, next the centre, is one-thirtieth of the length of the whip, its thickness at the same end is three-fourths of the breadth, and the back-side is made parallel to the face for half the length of the whip, or to the tenth bar; the small end of the whip is square, and at its end is one-sixtieth of the length of the whip, or half the breadth at the great end.
3. From the centre of the shaft B to the nearest bar 1 of the lattice, is one-seventh of the whip; the remaining space of six-sevenths of the whip is equally divided into 19 spaces, so as to make 19 bars; one-ninth of one of these spaces is equal to the mortises for the bars, the tenons of which are made square where they enter and go through the whip, and consequently the mortises must be square also.
4. To prepare the whip for mortising, strike a gage-score at about three-fourths of an inch from the face on each side, and the gage-score, on the leading side 4, 5, will give the face of all the bars on that side; but on the other side, the faces of all the bars will fall deeper than the gage-score, according to a certain rule. To find the space to be set off for this purpose for each bar, construct a scale in the following manner:
5. Extend the compasses to any distance at pleasure, so that six times

that extent may be greater than the breadth of the whip at the seventh bar; set those six spaces off upon a straight line for a base, at the end of which raise a perpendicular; set off three spaces upon the perpendicular, and divide the two spaces that are farthest from the base line into six equal parts each, so that this quantity of two spaces may be equally divided into 12 spaces, marked out by 13 points; from each of these points draw a line to the opposite end of the base, as so many rays to a centre, and the scale is finished.

6. To apply this scale to any given case, set off the breadth of the whip at the last bar, (that is, the bar at the extremity of the sail,) from the centre of the scale along the base towards the perpendicular; and at this point raise a perpendicular to cut the ray nearest to the base; also set off the breadth of the whip at the seventh bar in the same manner, and at this point erect another perpendicular to cut the thirteenth radius. From the intersection of the perpendicular, (drawn upon the breadth of the last bar,) with the first of the thirteen radii, to the intersection of the other perpendicular with the thirteenth radius, draw an oblique line cutting all the rest, and the distances of each of these last-mentioned points of intersection from the base line is the space which the face of each bar is distant from the gage-line on the driving side.

7. These distances give a difference set off for each bar till the seventh, which same must be set off for all the rest to the first.

8. These mortises must be square to the leading side of the whip.

9. When the mortises are cut, let the face of the whip be sloped off so as to agree with the face of the bars in every part.

10. Two-fifths of the whip are the length of the last or longest bar.

11. Five-eighths of the longest bar must be on the driving side of the whip, and three-eighths on the leading side, each being reckoned from the middle of the whip.

12. The proportion of the mortises already given determines the size of the bars of the mortises, but their thickness must be diminished each way, so as to be only one-half at the ends; but the face must be kept of equal breadth all the way.

13. The leading side goes no farther than the fourth bar, and there only projects one-third of the projection of the last bar.

14. All the bars on the driving side are made hollowing in the arch of a circle, which begins to spring one-third of the length of the bars on the driving side from the whip; and the sweep is such, that if a straight line be applied to the face of the bar from the whip to the end, the face of the bar should leave the straight line about the breadth of the bar.

15. There ought to be three uplongs, as 3, 2, 10,———to the driving, and two to the leading side, as 5, 4, to strengthen the lattice. Dr Rees's *Cyclopædia.*

Mr Richard Hall Gower, a gentleman in the sea-service of the East India Company, has made some judicious experiments with a view of determining the proper angles of weather which ought to be given to the vanes of a vertical windmill: his general conclusion is, that each vane should be a spiral, generated by the circular motion of a radius, and of a line moving at right angles to the plain of a circular motion. The construction he deduces from his inquiries is simple, being this:

The length, breadth, and angle of weather at the extremity of a vane being given; to determine the angles of weather at different distances from the centre.

Let A B, fig. 129, be the length of the vane; B C its breadth; and B C D the angle of the weather at the extremity of the vane, equal to 20 degrees. With the length of the vane A B, and breadth B C, construct the isosceles triangle A B C: from the point B draw B D perpendicular to C B, then B D is the proper depth of the vane.

Divide the line A B into any number of parts, (five for instance,) at those divisions draw the lines 1 E, 2 F, 3 G, and 4 H, parallel to the line B C; also, from the points of division 1, 2, 3, and 4, draw the lines 1 I, 2 K, 3 L, and 4 M, perpendicular to 1 E, 2 F, 3 G, &c. all of them equal in length to B D. Join E I, F K, G L, and H M: then the angles 1 E I, 2 F K, 3 G L, and H M, are the angles of weather at those divisions of the vane; and if the triangles be conceived to stand perpendicular to the plane of the paper, the angles I, K, L, M, and D, becoming the vertical angles, the hypothenuse of these triangles will, as before suggested, give a perfect idea of the weathering of the vane as it recedes from the centre.

METHOD OF CLOTHING AND UNCLOTHING THE SAILS WHILE IN MOTION.

Mr John Bywater, of Nottingham, took out a patent in 1804, for a method of clothing and unclothing the sails of windmills while in motion, by which the mill may be clothed either in whole or in part, in an easy and expeditious manner, by a few revolutions of the sails, whether they be going fast or slow, leaving the surface smooth, even, and regular in breadth from top to bottom; and in like manner the cloth, or any part of it, may be rolled or folded up to the whip at pleasure, by simple and durable machinery.

Fig. 130, Nos. 1, 2, 3, are front views of the sails as unclothed, half clothed, and clothed.

Fig. 131, a ring of iron, or other material, about 4 inches wide, and ¾ of an inch thick, whose diameter must be sufficient to embrace the shaft-head, to which it must be well secured by the stays *a a*.

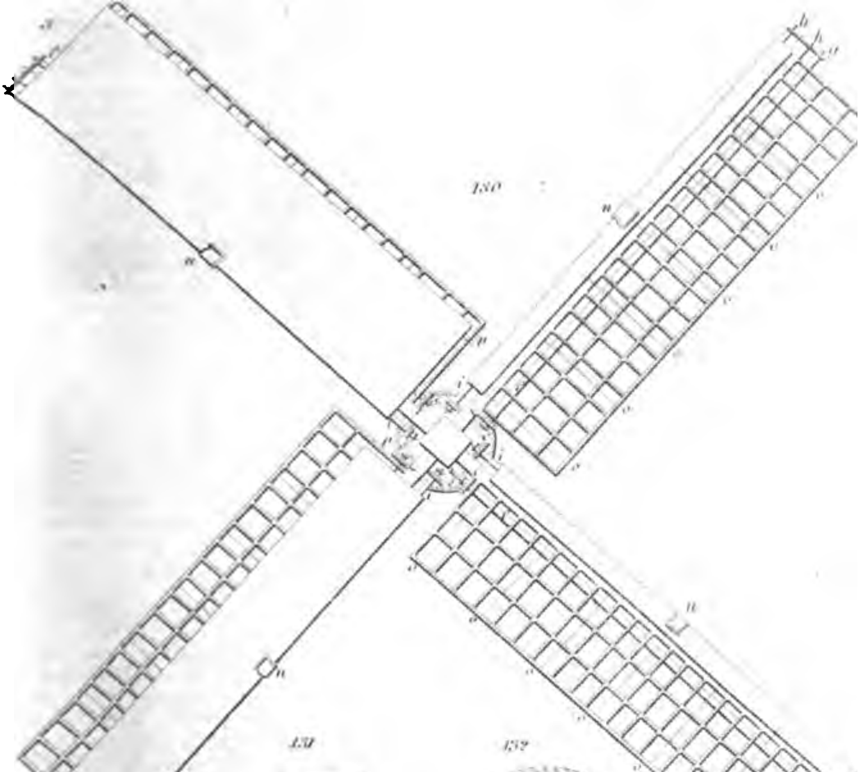
Fig. 132, a bevelled wheel, without arms, made of iron, stayed on the edge of the ring so as to turn easily.

Fig. 133, a spur-wheel of iron, without arms, made to turn easily on four pins fixed into four ears *b b b b*, in the back of the ring; which pins are turned up at their ends to keep it steady.

Fig. 134 is one of the four spindles of iron, or other material, with a spur nut *a*, and a beveled nut *b*; this spindle passes through fig. 131 at *c c c c*, and the nut *a* works into the spur-wheel as seen in fig. 135, *a a a a*. The four bevelled nuts, (fig. 134,) work into the bevelled wheels at the end of four cylinders *i i i i* fig. 130, Nos. 1, 2, 3, and so turn them; and two of these spindles must be shorter than the others when the stocks are not flush. These cylinders are made of wood of about 3 inches diameter, and are to be placed at the outside of the leading edge of each sail, round which the cloth is rolled, (one edge being fastened on for that purpose,) when the sail is unclothed. A gudgeon from the end of each cylinder runs into an iron fastened to the shaft-head, and is kept in its place by a nut screwed to its end. The other end has a gudgeon *b*, which turns in the eye of the cross iron *h*, at the points of the whips; *f f f f* four cylinders, similar to *i i i*, placed on the inside of the whips; one behind each sail to clothe the sails, by means of ropes *o o o o*, &c. fastened to them and the edge of the cloth. At the end of each of these four cylinders a nut or wheel is

From 130 to 139
p.130, 131.

130



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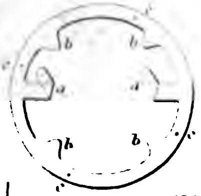

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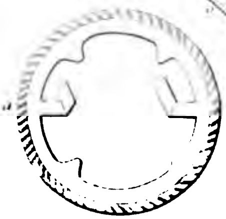

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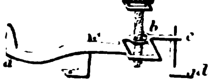

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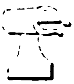

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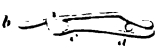

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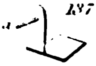

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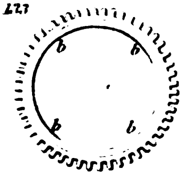

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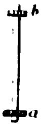

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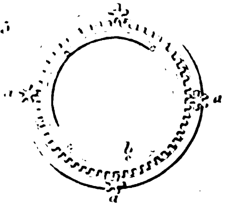

fixed, *e e e e*, to work into the bevelled wheel; fig. 132, whose teeth decline from the centre in proportion as these work from it, which declination must be reversed when the sails turn in the contrary way, and gudgeons to run into irons either projecting from the ring or fastened to the shaft-head like the other cylinders. The gudgeons *g* keep these cylinders steady in the cross iron *h* at the point of the whips, and stays of any shape or number will keep them from springing.

Now suppose the mill fully clothed, as at 3, all the parts of the machinery revolve with it undisturbed until a lever, fig, 136, which is fastened to the braces or fencing, by the centre pin *a*, fig. 137, on which it turns, and whose end *b* is weighted to hang down towards the breast of the mill, is brought into an horizontal direction, by pulling a string attached to the end *a* withinside the mill, which end *b* stops the stud *b*, projecting from the inner surface or back-front of the spur-wheel, fig. 135; consequently the four spur-nuts *a*, at the end of the spindle, fig. 134, and seen at *a a a a*, fig, 135, roll round the spur-wheel, and the bevelled nuts *b* at the other end of the spindle work into the bevelled wheels of the outside cylinders *i i i i*, at 1, 2, 3, in a straight direction behind them, and so turning the cylinders roll the cloth on them till it is rolled up to the whip. The lever is then driven sideways, (its spring *c* returning it again,) from the stud in the back face of the spur-wheel by the following contrivance:

A screw, *b*, fig. 138, is cut on the gudgeon of any one of the cylinders behind the sail, and a piece of iron, *c*, is tapped to fit it. The end of this iron runs into a slot in the iron *d*, made fast to the shaft-head, to prevent the iron *c* from turning with the cylinder, but allows it to slide up and down so as to press on that on the iron *a*, which has the eye in it, and raises the end *a* just high enough to drive the lever aside when the cloth is all rolled up, the thread of the screw adjusting it to what number of revolutions you choose to employ for that purpose. The point-end of the iron *a*, is that part of it which pushes aside and passes the lever, fig. 136, and moves on its centre *c*, and must be carried under the spur-wheel so as to act behind it for that purpose. By letting go the string, the miller may at any time leave the cloth on the sail where he chooses, likewise the sails may be clothed, or any part thereof, by a lever, similar to *a*, stopping the stud *a*, on the edge of the bevelled wheel, fig. 132, and driven off in a manner similar to the spur-wheel.

Fig. 139 is a stay of wood, fixed to the stock or whip at *n n n n*, 1, 2, 3, to prevent the cylinders from springing too much. In the inside there is left room enough for the cloth to be rolled upon the cylinder through its lips in the eye of this stay. In order to keep the strings, which go over the edge of the shrouds *o o o o*, &c. tight in all weathers, a cord, passing over a spring of any sort or shape, placed under the sail, is fastened to and wound about the upper ends of the cylinders, in a direction contrary to the strings and cloth. To prevent the strings from being driven downwards by the centrifugal force, a ring or two are left on to run along the rods in the old manner as *p*, Nos. 2, 3.

The width of the cloth, diameter of the cylinders, and number of revolutions you choose to employ to roll up your cloth, must determine the size of the wheels. In order to fold the cloth instead of rolling it, one end of it must be fastened to the whip and lines passed across the outside of it through loops fastened to its edge, and consequently over the edge of the shrouds, and connected with the cylinder or roller, of any shape, placed under the sail, or elsewhere, the other ends of the lines must be connected with the said cylinder or roller; and when the cloth is drawn up in folds towards the whip, so much of these lines will be rolled on the cylinder one way, and off from it the other, as will be sufficient to let out the cloth again when the same cylinder, turning the contrary way, draws the cloth on the sail. By this mode the patentee gets rid of four cylinders, with their appendages, the work being in other respects the same as in rolling the cloths; but since folding gives a surface much inferior in many respects to rolling, and induces inconveniences and accidents from which the rolled surface is free, he advises the rolling, rather than for a small saving to endure the inconveniences of folding.

If a sudden gust of wind should arise in the absence of the miller, so as to drive the mill faster than a given velocity, a pair of centrifugal balls, like the governor of a steam engine, may be so placed as to adjust the lever, so that it may immediately unclothe itself.

BAINES'S VERTICAL WINDMILL SAILS.

Mr. Robert Raines Baines, of Myton, Kingston upon Hull, secured to himself in June, 1815, by patent, an improvement in the construction of vertical mindmill sails.

Fig. 140 represents six sails; the stocks or arms marked A are the same as used for common vertical windmills; the sails marked B are made of canvass, and fastened to the front sides of the said stocks or arms along the edges marked *a*, *a*, and to the rods or bars marked D, at or near the point marked *b*, and are also extended by the rods or bars marked E, which are inserted into or fixed to the backs thereof, and by rods or bars marked *m*, which are inserted into or fastened to the edges of the said sails; each sail is also connected by a bar or rod marked F, as hereinafter described, with the next following sail. The shafts or rods marked C are fastened to the stocks or arms marked A, at or near *d*, *d*, by loops or otherwise, so as to allow them to move as hinges do. The bars or rods marked D are each of them connected with the shafts or rods marked C by a joint, which will allow the said bars or rods marked D to move from the wind independent of the shafts or rods marked C, in case it should blow against the back sides of the said sails, but will not allow the said bars or rods marked D to move from the wind independent of the said shafts or rods marked C, when the wind blows against the front sides of the said sails. The bars or rods marked F connect the corners marked *e* of each sail with the corner of the next following sail at or near the point marked *b*, leading behind such following sail, and which bars or rods are fastened by hooks or other proper means, at or near their points, bent to such an angle that if the wind should blow against the back sides of the said sails and force them forward, the said bars or rods will be unhooked and set at liberty. A rim or circle marked G is fixed by screws or otherwise upon the said stocks or arms marked A, for the purpose of supporting the fulcra or props marked H. At I is represented the head or end of a rod or bar which passes through the centre of the axletree of the mill, and to which weight may be applied, in the manner well known to mill-wrights, to regulate the said sails towards or from the wind. The bars or cranks marked K are fixed to the shafts or rods marked C, at such an angle, and in such a manner as will, when and as they are acted upon by the levers or bars marked L, either suffer the said bars or rods marked D and the sails to recede from the wind until the said sails present only their edges to it, or will force the said bars or rods marked D towards the wind, until they present to it their breadth. The levers or bars marked L are connected at one of their ends with the head of the aforesaid rod marked I, and at the other ends with the bars or cranks marked K, and form levers resting or acting upon the fulcra or props marked H, and are governed or regulated in their action by the said rod, the head of which is shown at I. The said rods, bars, cranks, loops, and rim, may be made of iron, or other suitable material or materials, and connected at their proper places by joints or otherwise, (so as to fix them or allow their action,) by modes well known to mill-wrights.

CUBITT'S METHOD OF EQUALIZING THE MOTION OF THE SAILS OF WINDMILLS.

Mr William Cubitt, of North Walsham, Norfolk, engineer, took out a patent for this invention in May, 1807, which the specification thus describes:

"My invention consists in applying to windmills an apparatus or contrivance which shall cause the vanes, constructed or formed in a new and peculiar manner, to regulate themselves, so as to preserve an uniform velocity under those circumstances in which the wind would otherwise irregularly impel them, as is the case with the sails or vanes of mills of the present construction. I accomplish this object by forming the vanes, (for the sake of lightness,) with fewer cross bars or shrouds than in the common method, and filling up the remaining open space with small flat surfaces, formed either of boards or sheet iron painted, or any other fit substance, (though I prefer and recommend them to be made of a framing of wood, covered over with canvass.) I hang or suspend the same on their ends by gudgeons, pivots, centres, or any other convenient method, so as to open and shut like valves, (for which reason I shall hereafter so call them,) preferring always to have the centre of motion as near the upper longitudinal edge of the valve as possible, as shown in the drawing, *b b*, fig. 141, which exhibits a valve detached. I apply these valves to vanes of the present construction, by suspending them to the cross bars or shrouds of the vane by their longitudal edges, fastened thereto by joints or otherwise, as may be preferred. These vanes, constructed of valves as above described, and which are represented in the drawing, fig. 142, present a greater or less surface to the wind, according as it acts with more or less force on them; and if the wind be very strong or high, the valves, by its impulse, would turn their edges to it, and their surfaces parallel to the direction of the wind; the vanes would consequently remain stationary, or at least have but little motion; but to obviate this circumstance taking place, I apply an apparatus which shall cause the valves always to present their flat surfaces to the wind, or such portion of their surfaces as may be desirable. The apparatus which I have usually applied is exhibited in the drawings, figs. 143 and 144, which last figure shows two modes of performing this object; though it must be evident that various other means may be applied to produce the same effect on the valves, and I therefore do not mean to confine myself to those precise modes of effecting it, but consider it unnecessary here to detail others, as the examples exhibited in the drawings fully ascertain the sort of apparatus requisite.

"Fig. 142 represents a set of vanes, in which A A shows the valves turned to the wind, and their surfaces all exposed at right angles with the direction of the wind; B B exhibit the vanes as close reefed, or the valves with their edges to the wind, so that it can have no effect upon them except on their edges, which must be trifling. In the drawing, the vanes are exhibited as having the whip down the middle, with valves on both sides; but it is evident that the vanes may be constructed with the whip placed in the usual way, and have valves on one side only, which is the method I usually adopt in applying them to vanes of the present form.

"Fig. 143 represents a side view of the apparatus for regulating the valves; and fig. 144 is a section of the same, exhibiting two methods of performing this operation. A represents the shaft, which is bored through its centre to admit an iron rod B to pass freely through it; one end of this rod is made to turn in a box C, which is fastened to a toothed rack D, whose teeth take into those of a pinion E, upon the axis of which is a sheave F, with a groove on its circumference to receive a rope G, to which is hung a weight, shown at H, fig. 143, and which must be sufficient to regulate the force of the wind upon the valves, though no precise quantity of weight can be herein specified, as the same must be adjusted by experiment, or by the quantity of work to be performed by the mill. On the top of the rack D is a roller I, which serves to keep the rack and pinion in the proper depth of geer. The end of the rod B, which turns in the box C, has a knob or onion on it, by which it can be moved endwise while it is turning in the box C. In the other end of the rod is fixed a boss or plate of iron K, with a gudgeon projecting from each side, on which are the bridles or leaders L L, which permit the levers M M to describe a curve with their ends while the iron rod B moves in a straight line. N N are two studs or props fixed to the stock O of the sail; on the ends of which props the levers M M move, and communicate their motion to the racks P P, the teeth of which take into the pinions Q Q, on the axis of which, (according to one method herein exhibited, fig. 145,) is fixed a strong iron stud R, which is attached to a rack or slider S. Iron studs or levers are fixed at one end in this slider S by a pin or gudgeon, and at the other made fast to the valves *a*, which move on gudgeons as before described.

"The other method of regulating the valves is shown at

WINDMILLS

From 140 to 146

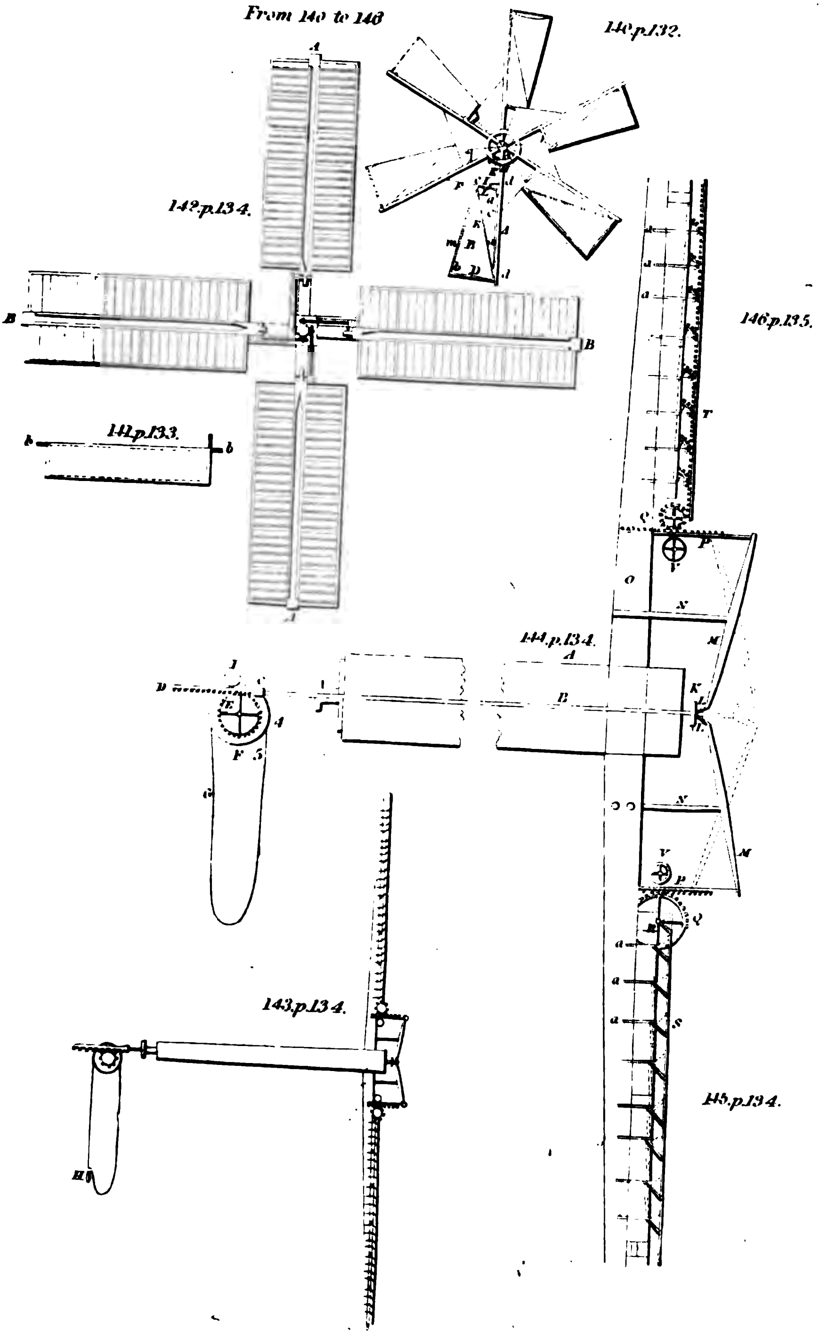

fig. 146, where instead of the studs or levers, the valves may be moved by having pinions fixed to them, and working with teeth in a rack or slider, as at T. V V are rollers to keep the racks P in their geer. The operation of this apparatus will be clearly comprehended by imagining that if the hook 4, on the rope G, be pulled down to 5, the sheave F with the pinion E will turn at the same time, putting in motion the rack D with the rod B, which will bring the levers M M into the position represented by the dotted lines: the racks P will have turned the pinion Q till the sliders S and T, with the studs or levers, or racks, (according to whichever method may be used,) bring the valves into the position of the dotted lines, in which position they are represented as having all their surfaces to the wind; therefore, if a sufficient weight be hung to the hook 4, the weight will descend to 5, and keep the valves in the situation of the dotted lines; and supposing the wind to blow upon them with too much force in this state, they will turn on their gudgeons, and raise the weights, so that the superfluous wind will pass through or between them, without exerting an irregular force upon the vanes, so as to produce an unequal velocity."

MILL WITH EIGHT QUADRANGULAR SAILS.

This mill, which is the invention of Mr James Verrier, is represented in fig. 147.

A A A are the three principal posts, 27 feet 7½ inches long, 22 inches broad at their lower extremities, 18 inches at their upper, and 17 inches thick. The column B is 12 feet 2½ inches long, 19 inches in diameter at its lower extremity, and 16 inches at its upper: it is fixed in the centre of the mill, passes through the first floor E, having its upper extremity secured by the bars G G. E E E are the girders of the first floor, one of which only is seen, being eight feet three inches long, 11 inches broad, and nine thick; they are mortised into the posts A A A and the column B, and are about eight feet three inches distance from the ground floor. D D D are three posts, six feet four inches long, nine inches broad, and six inches thick: they are mortised into the girders E F of the first and second floor, at the distance of two feet four inches from the posts A, &c. F F F are the girders of the second floor, six feet long, 11 inches broad, and nine thick: they are mortised into the posts A, &c., and rest upon the upper extremities of the post D, &c. The three bars G G G are 3 feet 1½ inches long, seven inches broad, and three thick: they are mortised into the posts D and the upper end of the column B, four feet three inches above the floor. P is one of the beams which support the extremities of the bray-trees or brayers; its length is two feet four inches, its breadth eight inches, and its thickness six inches. I is one of the bray-trees into which the extremity of one of the bridge-trees K is mortised. Each bray-tree is 4 feet 9½ inches long, 9½ inches broad, and seven thick, and each bridge-tree is four feet six inches long, nine inches broad, and seven thick; being furnished with a piece of brass on its upper surface to receive the under pivot of the mill-stones. L L are two iron screw-bolts, which raise or depress the extremities of the bray-trees. M M M are the three mill-stones, and N N N the iron spindles or arbors on which the turning mill-stones are fixed. D is one of three wheels or trundles which are fixed on the upper ends of the spindles N N N; they are 16 inches in diameter, and each is furnished with 14 staves; *f* is one of the carriage-rails on which the upper pivot of the spindle turns, and is four feet two inches long, seven inches broad, and four thick. It turns on an iron bolt at one end, and the other end slides in a bracket fixed to one of the joints, and forms a mortise in which a wedge is driven to set the rail and trundle in or out of work: *t* is the horizontal spur-wheel that impels the trundles; it is five feet six inches in diameter, is fixed to the perpendicular shaft T, and is furnished with 42 teeth. The perpendicular shaft T is nine feet one inch long, and 14 inches in diameter, having an iron spindle at each of its extremities; the under spindle turns in a brass block fixed into the higher end of the column B; and the upper spindle moves in a brass plate inserted into the lower surface of the carriage-rail C. The spur-wheel *r* is fixed on the upper end of the shaft T, and is turned by the crown-wheel *v* on the wind shaft *c;* it is three feet two inches in diameter, and is furnished with 15 cogs. The carriage rail C, which is fixed on the sliding kerb Z, is 17 feet 2 inches long, one foot broad, and nine inches thick. Y Y Q is the fixed kerb, 17 feet 3 inches diameter, 14 inches broad, and 10 thick, and is mortised into the posts A A A, and fastened with screw-bolts. The sliding kerb Z is of the same diameter and breadth as the fixed kerb, but its thickness is only 7½ inches; it revolves on 12 friction rollers fixed on the upper surface of the kerb Y Y Q, and has four iron half-staples, Y, Y, &c. fastened on its outer edge, whose perpendicular arms are 10 inches long, two inches broad, and one inch thick, and embrace the outer edge of the fixed kerb, to prevent the sliding one from being blown off. The capsills X V are 13 feet 9 inches long, 14 inches broad, and 1 foot thick: they are fixed at each end with strong iron screw-bolts to the sliding kerb, and to the carriage-rail C. On the right hand of *w* is seen the extremity of a cross-rail, which is fixed into the capsills X V by strong iron bolts; *e* is a bracket 5 feet long, 16 inches broad, and 10 inches thick; it is bushed with a strong brass collar, in which the inferior spindle of the windshaft turns, and is fixed to the cross-rail *w; b* is another bracket, seven feet long, four feet broad, and 10 inches thick; it is fixed into the four ends of the capsills, and in order to embrace the collar of the windshaft, it is divided into two parts, which are fixed together with screw-bolts. The windshaft *c* is 15 feet long, two feet in diameter at the fore end, and 18 inches at the other; its pivot at the back end is six inches diameter; and the shaft is perforated, to admit an iron rod to pass easily through it. The vertical crown-wheel *v* is six feet in diameter, and is furnished with 54 cogs, which drive the spur-wheel *r;* the bolster *d*, which is six feet three inches long, 13 inches broad, and half a foot thick, is fastened into the cross-rail *w*, directly under the centre of the windshaft, having a brass pully fixed at its fore end. On the upper surface of this bolster is a groove in which the sliding bolt R moves, having a brass stud at its fore end. This sliding bolt is not distinctly seen in the figure, but the round top of the brass stud is visible below the letter *h;* the iron rod that passes through the windshaft bears against this brass stud. The sliding bolt is four feet nine inches long, nine inches broad, and one-third of a foot thick. At its fore end is fixed a line which passes over the brass pulley in the bolster, and appears at *a* with a weight attached to its extremity, sufficient to make the sails face the wind that is strong enough for the number of stones employed: and when the pressure of the wind is more than sufficient, the sails turn on an edge and press back the sliding bolt, which prevents them from moving with too great velocity:

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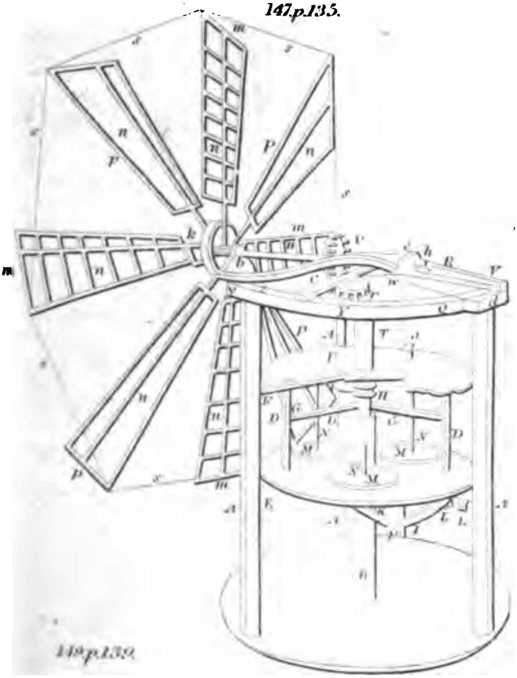
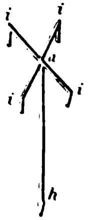
From 147 to 151

Pl 15

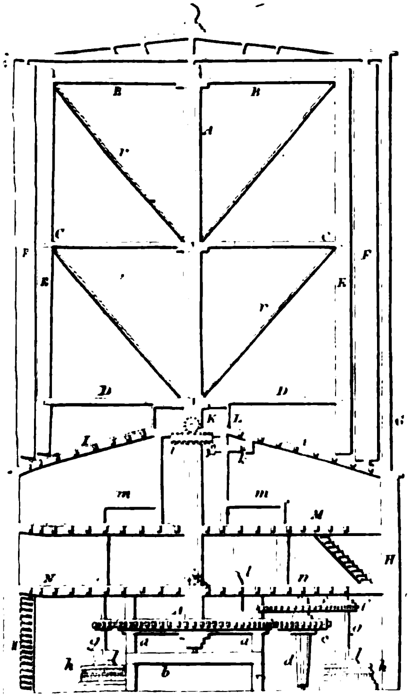
147.p.135.



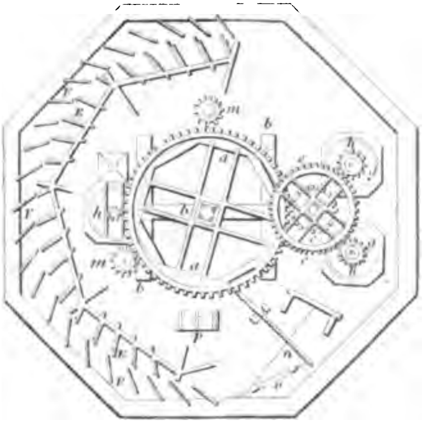
148.p.137



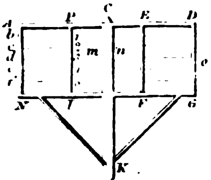
149.p.139.



150.p.139, 40.



151.p.140.



and as soon as the wind abates, the sails, by the weight *a*, are pressed up to the wind till its force is sufficient to give the mill a proper degree of velocity. By this apparatus the wind is regulated and justly proportioned to the resistance, or work to be performed; an uniformity of motion is also obtained, and the mill is less liable to be destroyed by the rapidity of its motion.

That the reader may understand how these effects are produced, we have represented in fig. 148, the iron rod, and the arms which bear against the vanes; *a h* is the iron rod which passes through the windshaft *c*, in fig. 147; *h* is the extremity which moves in the brass stud that is fixed upon the sliding bolt; *a i*, *a i*, &c. are the cross-arms at right angles to *a h*, whose extremities *i*, *i*, similarly marked in fig. 147, bear upon the edges of the vanes. The arms *a i* are 6½ feet long, reckoning from the centre *a*, one foot broad at the centre, and five inches thick; the arms *n*, *n*, &c. that carry the vanes or sails, are 18½ feet long, their greatest breadth is one foot, and their thickness nine inches, gradually diminishing to their extremities, where they are three inches in diameter. The four cardinal sails, *m*, *m*, *m*, *m*, are each 13 feet long, eight feet broad at their outer end, and three feet at their lower extremities; *p*, *p*, &c. are the four assistant sails which have the same dimensions as the cardinal ones, to which they are joined by the line S S S S. The angle of the sail's inclination when first opposed to the wind is 45 degrees, and regularly the same from end to end.

It is evident from the preceding description of this machine, that the windshaft *c* moves along with the sails; the vertical crown-wheel *v* impels the spur-wheel *r*, fixed upon the axis T, which carries also the spur-wheel *t*. This wheel drives the three trundles H, one of which only is seen in the figure, which being fixed upon the spindles N, &c. communicate motion to the turning mill-stones.

That the wind may act with the greatest efficacy upon the sails, the windshaft or principal axis must always have the same direction as the wind. But as this direction is perpetually changing, some apparatus is necessary for bringing the windshaft and sails into their proper position. As both the common methods of adjusting the windshaft require human assistance, it would be very desirable that the same effect should be produced solely by the action of the wind. This may be done by fixing a large wooden vane or weathercock at the extremity of a long horizontal arm which lies in the same vertical plane with the windshaft. By this means, when the surface of the vane and its distance from the centre of motion are sufficiently great, a very gentle breeze will exert a sufficient force upon the vane to turn the machinery, and will always bring the sails and windshaft to their proper position. This weathercock, it is evident, may be applied either to machines which have a movable roof, or to those which revolve upon a vertical arbor. Prior to the French revolution, windmills were more numerous in Holland and the Netherlands than in any other part of the world, and there they seem to have been brought to a very high state of perfection. This is evident not only from the experiments of Mr Smeaton, from which it appears that sails weathered in the Duch manner produced nearly a maximum effect, but also from the observations of the celebrated Coulomb. This philosopher examined above 50 windmills in the neighbourhood of Lisle, and found that each of them performed nearly the same quantity of work when the wind moved with the velocity of 18 or 20 feet per second, though there were some trifling differences in the inclination of their windshafts, and in the disposition of their sails. From this fact, Coulomb justly concluded that the parts of the machine must have been so disposed as to produce nearly a maximum effect.

In the windmills on which Coulomb's experiments were made, the distance from the extremity of each sail to the centre of the windshaft or principal axis was 33 feet. The sails were rectangular, and their width was a little more than six feet, five of which were formed with cloth stretched upon a frame, and the remaining foot consisted of a very light board. The line which joined the board and the cloth formed, on the side which faced the wind, an angle sensibly concave at the commencement of the sail, which diminished gradually till it vanished at its extremity. Though the surface of the cloth was curved, it may be regarded as composed of right lines perpendicular to the arm or whip which carries the frame, the extremities of these lines corresponding with the concave angle formed by the junction of the cloth and the board. Upon this supposition, these right lines at the commencement of the sail, which was distant about six feet from the centre of the windshaft, formed an angle of 60 degrees with the axis or windshaft, and the lines at the extremity of the wing formed an angle increasing from 78 to 84 degrees, according as the inclination of the axis of rotation to the horizon increased from 8 to 15 degrees; or in the mill-wright's terms, the greatest angle of weather was 30 degrees, and the least varied from 12 to 6 degrees, as the inclination of the windshaft varied from 8 to 15 degrees. A pretty distinct idea of the surface of windmill sails may be conveyed by conceiving a number of triangles standing perpendicular to the horizon, in which the angle contained between the hypothenuse and the base is constantly diminishing; the hypothenuse of each triangle will then be in the superficies of the vane, and they would form that superficies if their number were infinite.

ON HORIZONTAL WINDMILLS.

A variety of opinions have been entertained respecting the relative advantages of horizontal and vertical windmills. Mr Smeaton gives a decided preference to the latter; but, when he asserts that horizontal windmills have only one-eighth or one-tenth of the power of vertical ones, he certainly forms too low an estimate of their power. Mr Beatson, on the contrary, who has a patent for the construction of a new horizontal windmill, seems to be prejudiced in their favour. From an impartial investigation, it will probably appear, that the truth lies between these two opposite opinions; but before entering on this discussion, we must first consider the nature and form of horizontal windmills; which we shall do in presenting the reader with a description of the horizontal mill erected at Margate by Captain Hooper.

Fig. 149 is an upright section, and fig. 150 a plan of the building. H H are the side walls of an octagonal building which contains the machinery. These walls are surmounted by a strong timber framing G G, of the same form as the building, and connected at top by cross-framing to support the roof, and also the upper pivot of the main vertical shaft A A, which has three sets of arms, B B, C C, D D, framed upon it at that part which rises above the height of the walls. The arms are strengthened and supported by diagonal braces, and their extremities are bolted to octagonal wood frames, round which the vanes or floats E E are fixed, as seen in outline in fig. 150, so as to form a large wheel, resembling a water-wheel, which is less than the size of the house by about 18 inches all round. This space is occupied by a number of vertical boards or blinds F F, turning on pivots at top and bottom, and placed obliquely, so as to overlap each other, and completely shut out the wind, and stop the mill, by forming a close case surrounding the wheel; but they can be moved altogether upon their pivots to allow the wind to blow in the direction of a tangent upon the vanes on one side of the wheel, at the time the other side is completely shaded or defended by the boarding. The position of the blinds is clearly shown at F F, fig. 150. At the lower end of the vertical shaft A A, a large spur-wheel *a a* is fixed, which gives motion to a pinion *c*, upon a small vertical axis *d*, whose upper pivot turns in a bearing bolted to a girder of the floor *n*. Above the pinion *c*, a spur-wheel *e* is placed, to give motion to two small pinions *f*, on the upper ends of the spindles *g*, of the mill-stone *h*. Another pinion is situate at the opposite side of the great spur-wheel *a a*, to give motion to a third pair of mill-stones, which are used when the wind is very strong; and then the wheel turns so quick as not to need the extra wheel *e* to give the requisite velocity to the stones. The weight of the main vertical shaft is borne by a strong timber *b*, having a brass box placed on it to receive the lower pivot of the shaft. It is supported at its ends by cross-beams mortised into the upright posts *b b*, as shown in the plan, fig. 150. A floor or roof I I is thrown across the top of the brick building to protect the machinery from the weather, and to prevent the rain blowing down the opening through which the shaft descends, a broad circular hoop K is fixed to the floor, and is surrounded by another hoop or case L, which is fixed to the arms D D of the wheel. This last is of such a size, as exactly to go over the hoop K, without touching it when the wheel turns round. By this means, the rain is perfectly excluded from the upper room M, which serves as a granary, being fitted up with the bins *m m*, to contain the different sorts of grain which is raised up by the sack-tackle. A wheel *i* is fixed on the main shaft, having cogs projecting from both sides. Those at the under side work into a pinion on the end of the roller K, which is for the purpose of drawing up sacks. Another pinion is situated above the wheel *i*, which has a roller projecting out over the flap-doors seen at *p*, in fig. 150, to land the sacks upon. The two pinions *m m*, fig. 150, are turned by the great wheel *a a*, and are for giving motion to the dressing and bolting machines, which are placed upon the floor N, but are not shown in the drawing, being exactly similar to the dressing machines used in all flour mills. The cogs upon the great wheel *a* are not so broad as the rim itself, having a plain rim about three inches broad. This is encompassed by a broad iron hoop, which is made fast at one end to the upright post *b;* the other being jointed to a strong lever *n*, to the extreme end of which a purchase *o* is attached, and the fall is made fast to iron pins on the top of a frame fixed to the ground. This apparatus answers the purpose of the brake or gripe used in common windmills to stop their motion. By pulling the fall of the purchase *o*, it causes the iron strap to embrace the great wheel, and produces a resistance sufficient to stop the wheel. The mill can be regulated in its motion, or stopped entirely, by opening or shutting the blinds F, which surround the fan-wheel. They are all moved at once by a circular ring of wood situated just beneath the lower ends of the blinds upon the floor I I, being connected with each blind by a short iron link. The ring is moved round by a rack and spindle which descend into the mill-room below, for the convenience of the miller.

The mode of bringing the sails back against the wind, which Mr Beatson invented, is, perhaps, the simplest and best for that end. He makes each sail A I, fig. 151, to consist of six or eight flaps or vanes. A P, *b* 1, *b* 1, *c* 2, &c. moving upon hinges represented by the dark lines, A P, *b* 1, *c* 2, &c. so that the lower side *b* 1 of the first flap wraps over the hinge or higher side of the second flap, and so on. When the wind, therefore, acts upon the sail A I, each flap will press upon the hinge of the one immediately below it, and the whole surface of the sail will be exposed to its action. But when the sail A I returns against the wind, the flaps will revolve round upon their hinges, and present only their edges to the wind, as is represented at E G, so that the resistance occasioned by the return of the sail must be greatly diminished, and the motion will be continued by the great superiority of force exerted upon the sails in the position A I. In computing the force of the wind upon the sail A I, and the resistance opposed to it by the edges of the flaps in E G, Mr Beatson finds, that when the pressure upon the former is 1872 pounds, the resistance opposed by the latter is only about 36 pounds, or one-fifty-second part of the whole force; but he neglects the action of the wind upon the arms, C A, &c. and the frames which carry the sails, because they expose the same surface in the position A I, as in the position E G. This omission, however, has a tendency to mislead us in the present case, as we shall now see; for we ought to compare the whole force exerted upon the arms, as well as the sail, with the whole resistance which these arms and the edges of the flaps oppose to the motion of the windmill. By inspecting the figure it will appear, that if the force upon the edges of the flaps, which Mr Beatson supposed to be 12 in number, amounts to 36 pounds, the force spent upon the bars C D, D G, G F, F E, &c. cannot be less than 60 pounds. Now, since these bars are acted upon with an equal force, when the sails have the position A I, $1872 + 60 = 1932$ will be the force exerted upon the sail A I and its appendages, while the opposite force upon the bars and edges of the flaps when returning against the wind will be 36 + 60 = 96 pounds, which is nearly one-twentieth of 1932, instead of one-fifty-second, as computed by Mr Beatson. Hence we may see the advantages which will probably arise from using a screen for the returning sail instead of movable flaps, as it will preserve not only the sail, but the arms and the frame which supports it, from the action of the wind.*

Mr Brewster makes also the following remark on the comparative power of horizontal and vertical windmills. It has been already stated, that Mr Smeaton rather underrated the former while he maintained that they have only one-eighth or one-tenth the power of the latter. He observes, that when the vanes of a horizontal and a vertical mill are of the same dimensions, the power of the latter is four times that of the former; because, in the first case, only one sail is acted upon at once; while, in the second case, all the four receive the impulse of the wind. This, however, is not strictly true, since the vertical sails are all oblique to the direction of the wind. Let us suppose that the area of each sail is 100 square feet; then the power of the horizontal sail may be called $100 \times \sin.^2 70^\circ$, (which is the common angle of inclination,) = 88 nearly; but since there are four vertical sails, the power of them all will be $4 \times 88 = 352$: so that the power of the horizontal sail is to that of the four vertical ones as 1 to 3.52, and not as 1 to 4, according to Mr Smeaton. But Mr Smeaton also observes, that if we consider the further disadvantages which arises from the difficulty of getting the sails back against the wind, we need not wonder if horizontal windmills have only about $\frac{1}{8}$ or $\frac{1}{10}$ of the common sort. We have already seen that the resistance occasioned by the return of the sails amounts to $\frac{1}{20}$ of the whole force which they received; by subtracting $\frac{1}{20}$ therefore, from $\frac{1}{352}$, we shall find that the power of horizontal windmills is only $\frac{1}{4}{:}\frac{03}{40}$, or little more than one-fourth less than that of vertical ones. This calculation proceeds upon a supposition that the whole force exerted upon vertical sails is employed in turning them round the axis of motion; whereas a considerable part of this force is lost in pressing the pivot of the axis or windshaft against its gudgeon. Mr Smeaton has overlooked this circumstance, otherwise he could never have maintained that the power of four vertical sails was quadruple the power of one horizontal sail, the dimensions of each being the same. Taking this circumstance into the account, we cannot be far wrong in saying that, in theory at least, if not in practice, the power of a horizontal windmill is about one-third or one-fourth of the power of a vertical one, when the quantity of surface and the form of the sails are the same, and when all the parts of the horizontal sails have the same distance from the axis of motion as the corresponding parts of the vertical sails. But if the horizontal sails have the position A I, E G, in fig. 151, instead of the position C A *d m*, C D *o n*, their effect will be greatly increased, though the quantity of surface is the same; because the part C P 3 *m* being transferred to B I 3 *d*, has much more power to turn the sails. Having this method, therefore, of increasing the effect of horizontal sails, which cannot be applied to vertical ones, we would encourage every attempt to improve their construction, as not only laudable in itself, but calculated to be of essential utility in a commercial country.—See Dr Brewster's valuable Appendix to Ferguson's *Lectures*.

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* The sails of horizontal windmills are sometimes fixed like float-boards on the circumference of a large drum or cylinder. These sails move upon hinges so as to stand at right angles to the drum, when they are to receive the impulse of the wind; and when they return against it, they fold down upon its circumference.

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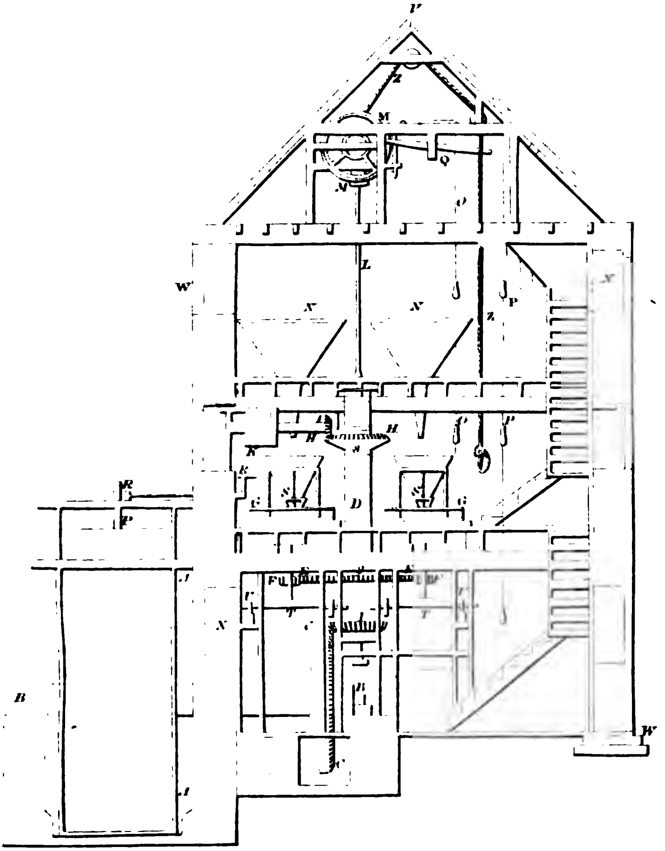
FLOUR-MILLS.

In fig. 152 we have given a section of a double flour-mill, reduced from Gray's Experienced Mill-wright, with the following account:

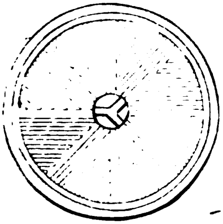
A A, the water-wheel. B B, its shaft or axle. C C, a wheel fixed upon the same shaft, containing 90 teeth or cogs, to drive the pinion No 1, having 23 teeth, which is fastened upon the vertical shaft D. No. 2, a wheel fixed upon the shaft D, containing 82 teeth, to turn the two pinions F F, having 15 teeth, which are fastened upon the iron axles or spindles that carry the two upper mill-stones. E E, the beam or sill that supports the frame on which the under mill-stones are laid. G G, the cases or boxes that enclose the upper mill-stones; they should be about two inches distant from the stone all round its circumference. T T, the bearers, called bridges, upon which the under end of the iron spindles turn. These spindles pass upwards through a hole in the middle of the nether mill-stones, in which is fixed a wooden bush that their upper ends turn in. The top part of the spindles, above each wooden bush, is made square, and goes into a square hole in an iron cross, which is admitted into grooves in the middle and under surface of the upper mill-stone. By this means that stone is carried round along with the trundles F F, when turned by the wheel No. 2. One end of the bridges T T is put into mortises in fixed bearers; and the other end into mortises in the bearers that move at one end on iron bolts, their other ends hanging by iron rods having screwed nuts, as U U; so that when turned forward or backward they raise or depress the upper mill-stones, according as the miller finds it necessary. S S, the feeders, in the under end of each of which is a square socket that goes upon the square of

From 152 to 154

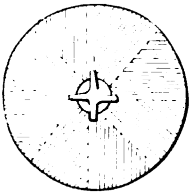
152.p.142.



156.p.143.



154.p.143.



the spindles above the iron cross or rind, and having three or four branches that move the spout or shoe, and feed the wheel constantly from the hoppers into the hole or eye of the upper mill-stone, where it is introduced betwixt the stones, and by the circular motion of the upper stone acquires a centrifugal force, and proceeding gradually from the eye of the mill-stone towards the circumference, is at length thrown out in flour or meal. R R, the sluice, machine, and handle, to raise the sluice, and let the water on the wheel A to drive it round. No. 3 is a wheel fixed upon the shaft D, containing 44 teeth, to turn the pinion No. 4, having 15 teeth, which is fastened upon the horizontal axle H. On this axle is also fixed the barrel K, on which go the two leathern belts that turn the wire engine and bolting mill. L, an iron spindle, in the under end of which is a square socket that takes in a square on the top of the gudgeon of the vertical shaft D. There is a pinion M, of nine teeth, fixed on the upper end of the spindle L, to turn the wheel M M, having 48 teeth, which is fastened upon the axle round which the rope Z Z rolls, to carry the sacks of flour up to the cooling benches. By pulling the cord O O a little, the wheel M M and its axle are put into motion, in consequence of that wheel and its axle being moved horizontally, until the teeth of the wheel are brought into contact with those of the pinion at the top of the spindle L: and, on the contrary, by pulling the cord P P, the wheel M and its axle are moved in the opposite horizontal direction, till they are thrown out of geer with the pinion, and the rotatory motion of that wheel stops. But when the sack of flour is raised up to the lever Q, it pushes up that end of the lever, and of course the other end down; by which means the pinion M is disengaged, and thus that part of the machine stops of itself. N N are two large hoppers, into which the clean wheat is put to be conveyed down to the hoppers S S, placed on the frame immediately above the mill-stones. W W, the side wall of the mill-house. V, the couples or frame of the roof. X X, windows to lighten the house.

Fig. 153 represents the surface of the under grinding mill-stone; the way of laying out the roads or channels; the wooden bush fixed into the hole in its middle, in which the upper end of the iron spindle turns round; and the case or hoops that surround the upper one, which ought to be two inches clear of the stone all round its circumference.

Fig. 154, the upper grinding mill-stone, and iron cross or rind in its middle; in the centre of which is a square hole that takes in a square on the top of the iron spindle, to carry round the mill-stone. When the working sides or faces of the mill-stones are laid uppermost, the roads, (or channels,) must lie in the same direction in both; so that when the upper stone is turned over, and its surface laid upon the under one, then the channels may cross each other, which assists in grinding and throwing out the flour, the sharp edges of the two furrows then cutting against each other like scissars. The roads are likewise laid out according to the way the upper stone revolves. In those represented in the figures, the running mill-stone is supposed to turn "sunway," or as in what is called a right-handed mill: but if the stone revolves the other way, the channels must be cut the reverse of this, and then the mill is termed a left-handed-one.

The mill-stones are of the utmost importance in the construction of flour-mills, as upon them principally depends the quality of the meal; we cannot, therefore, do better than to annex Mr Ferguson's opinion upon them, as also some subsequent remarks by his editor, Dr Brewster.

MILL-STONE.

The heavier the running mill-stone is, and the greater the quantity of water that falls upon the wheel, so much the faster will the mill bear to be fed, and consequently, so much the more it will grind: and on the contrary, the lighter the stone, and the less the quantity of water, so much slower must the feeding be. But when the stone is considerably wore, and become light, the mill must be fed slowly at any rate; otherwise the stone will be too much borne up by the corn under it, which will make the meal coarse.

The quantity of power required to turn a heavy mill-stone is but very little more than what is sufficient to turn a light one: for as it is supported upon the spindle by the bridge-tree, and the end of the spindle that turns in the brass foot therein being but small, the odds arising from the weight is but very inconsiderable in its action against the power or force of the water; and, besides, a heavy stone has the same advantage as a heavy fly, namely, that it regulates the motion much better than a light one.

In order to cut and grind the corn, both the upper and under mill-stones have channels or furrows cut into them, proceeding obliquely from the centre towards the circumference: and these furrows are cut perpendicularly on one side, and obliquely on the other, into the stone, which gives each furrow a sharp edge, and in the two stones they come, as it were, against one another like the edges of a pair of scissars, and so cut the corn, to make it grind the easier when it falls upon the place between the furrows. These are cut the same way in both stones when they lie upon their backs, which makes them run cross ways to each other when the upper stone is inverted, by turning its furrowed surface toward that of the lower. For, if the furrows of both stones lay the same way, a great deal of the corn would be driven onward in the lower furrows, and so come out from between the stones without being either cut or bruised.

When the furrows become blunt and shallow by wearing, the running stone must be taken up, and both stones new dressed with a chisel and hammer; and every time the stone is taken up, there must be some tallow put round the spindle upon the bush, which will soon be melted by the heat the spindle acquires from its turning and rubbing against the bush, and so will get in between them, otherwise the bush would take fire in a very little time.

The bush must embrace the spindle quite close, to prevent any shake in the motion, which would make some parts of the stones grate and fire against each other, while other parts of them would be too far asunder, and by that means spoil the meal in grinding.

Whenever the spindle wears the bush so as to begin to shake in it, the stone must be taken up and a chisel drove into several parts of the bush; and when it is taken out, wooden wedges must be driven into the holes; by which means the bush will be made to embrace the spindle close all round it again. In doing this, great care must be taken to drive equal wedges into the bush on opposite sides of the spindle, otherwise it will be thrown out of the perpendicular, and so hinder the upper stone from being set parallel to the under one, which is absolutely necessary for making good work. When any accident of this kind happens, the perpendicular position of the spindle must be restored by adjusting the bridge-tree by proper wedges put between it and the brayer.

It often happens that the rind is a little wrenched in laying down the upper stone upon it, or is made to sink a little lower upon one side of the spindle than upon the other; and this will cause one edge of the upper stone to drag all round upon the other, while the opposite edge will not touch. But this is easily set to rights, by raising the stone a little with a lever, and putting bits of paper, cards, or thin chips, between the rind and the stone.

The diameter of the upper stone is generally about six feet, the lower stone about an inch more; and the upper stone, when new, contains about 22½ cubic feet, which weighs somewhat more than 19,000 pounds. A stone of this diameter ought never to go more than 60 times round in a minute, for if it turns faster it will heat the meal.

The grinding surface of the under stone is a little convex from the edge to the centre, and that of the upper stone a little more concave: so that they are farthest from one another in the middle, and come gradually nearer towards the edges. By this means, the corn at its first entrance between the stones is only bruised; but as it goes farther on towards the circumference or edge, it is cut smaller and smaller; but at last finely ground just before it comes out from between them.*

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* The upper mill-stone, when six feet in diameter, is generally hollowed about one inch at the centre; and the under one rises about three-fourths of an inch. The corn that falls from the hopper insinuates itself between them as far as two-thirds of the radius where the grinding begins; the

When the furrows of mill-stones are worn shallow, and consequently new dressed with the chisel, the same quantity of stone must be taken from every part of the grinding surface, that it may have the same convexity or concavity as before. As the upper-mill stone should always have the same weight when its velocity remains unchanged, it will be necessary to add to it as much weight as it lost in the dressing. This will be most conveniently done by covering its top with a layer of plaster, of the same diameter as the layer of stone taken from its grinding surface, and as much thicker than the layer of stone, as the specific gravity of the stone exceeds the specific gravity of the plaster. That the reader may have some idea of the manner in which the furrows, or channels, are arranged, we have represented, fig. 154, the grinding surface of the upper mill-stone, upon the supposition that it moves from east to west, or for what is called a right-handed mill. When the mill-stone moves in the opposite direction, the position of the furrows must be reversed.

In fig. 156, we have a section of the mill-stone, spindle and lantern. The under mill-stone M P H G, which never moves, may be of any thickness. Its grinding surface must be of a conical form, the point *b* being about an inch above the horizontal line P R, and M *a* and P *b* being straight lines. The upper mill-stone E F P M, which is fixed to the spindle C D, at C, and is carried round with it, should be so hollowed that the angle O M *a*, formed by the grinding surfaces, may be of such a size that O *n*, being taken equal to *n* M, *n s* may be equal to the thickness of a grain of corn. The diameter O N of the mill-eye *m* C, should be between 8 and 14 inches; and the weight of the upper mill-stone E P, joined to the weight of the spindle C D, and the trundle *x*, (the sum of which three numbers is called the *equipage* of the turning mill-stone,) should never be less than 1550 pounds avoirdupois, otherwise the resistance of the grain would bear up the mill-stone, and the meal be ground too coarse.

In order to find the weight of the equipage; divide the third of the radius of the gudgeon by the radius of the water-wheel which it supports, and having taken the quotient from 2,25, multiply the remainder by the expense of the source, by the relative fall, and by the number 19,911, and you will have a first quantity, which may be regarded as pounds. Multiply the square root of the relative fall by the weight of the arbor of the water-wheel, by the radius of its gudgeon, and by the number 1617, and a second quantity will be had, which will also represent pounds. Divide the third part of the radius of the gudgeon by the radius of the water-wheel, and having augmented the quotient by unity, multiply the sum by 1005, and a third quantity will be obtained. Subtract the second quantity from the first, divide the remainder by the third, and the quotient will express the number of pounds in the equipage of the mill-stone.

The weight of the equipage being thus found, extract its

distance between the stones being there about two-thirds or three-fourths of the thickness of a grain of corn. This distance, however, can be altered at pleasure, by raising or sinking the upper stone.—*Dr Brewster.*

square root, expressed in pounds, and multiply it by 039, and the product will be the radius of the mill-stone in feet.

In order to find the weight and thickness of the upper mill-stone, the following rules must be observed:

1. To find the weight of a quantity of stone equal to the mill-eye; take any quantity which seems most proper for the weight of the spindle C D, and the lantern X, and subtract this quantity from the weight of the mill-stone's equipage, for a first quantity. Find the area of the mill-eye, and multiply it by the weight of a cubic foot of stone of the same kind as the mill-stone, and a second quantity will be had. Multiply the area of the mill-stone by the weight of a cubic foot of the same stone, for a third quantity. Multiply the first quantity by the second, and divide the product by the third, and the quotient will be the weight required.

2. To find the number of cubic feet in the turning mill-stone, supposing it to have no eye; from the weight of the spindle and lantern subtract the quantity found by the preceding rule for the first number. Subtract this first number from the weight of the equipage, and a second number will be obtained. Divide the second quantity by the weight of a cubic foot of stone of the same quality as the mill stone, and the quotient will be the number of cubic feet in E M P F, *m* C being supposed to be filled up.

3. To find the quantities *m* N and E M, i. e. the thickness of the mill-stone at its centre and circumference; divide the solid content of the mill-stone, as found by the preceding rule, by its area, and you will have the first quantity. And *b* R, which is generally about an inch, to twice the diameter of a grain of corn, for a second quantity. Add the first quantity to one-third of the second, and the sum will be the thickness of the mill-stone at the circumference. Substract the third of the second quantity from the first quantity, and the remainder will be its thickness at the centre.

The size of the mill-stone being thus found, its velocity is next to be determined. M. Fabre observes, that the flour is the best possible when a mill-stone five feet in diameter makes from 48 to 61 revolutions in a minute. Mr Ferguson allows 60 turns to a mill-stone six feet in diameter; and Mr Imison 120 to a mill-stone 4½ feet in diameter. In mills upon Mr Imison's construction, the great heat that must be generated by such a rapid motion of the mill-stone, must render the meal of a very inferior quality: much time, on the contrary, will be lost, when such a slow motion is employed as is recommended by M. Fabre and Mr Furguson. In the best corn-mills in this country, a mill-stone five feet in diameter revolves, at an average, 90 times in a minute. The number of revolutions in a minute, therefore, which must be assigned to mill-stones of a different size, may be found by dividing 450 by the diameter of the mill-stone in feet.

The spindle *c* D, which is commonly six feet long, may be made either of iron or wood. When it is of iron, and the weight of the mill-stone 7558 pounds avoirdupois, it is generally three inches in diameter; and when made of wood, it is 10 or 11 inches in diameter. For mill-stones of a different weight, the thickness of the spindle may be found by proportioning it to the square root of the mill-stone's weight, or which is nearly the same thing, to the weight of the mill-stone's equipage.

The greatest diameter of the pivot D, upon which the mill-stone rests, should be proportional to the square root of the equipage, a pivot half an inch diameter being able to support an equipage of 5398 pounds. In most machines, the diameter of the pivots is by far too large, being capable of supporting a much greater weight than they are obliged to bear. The friction is therefore increased, and the performance of the machine diminished.

The bridge-tree, A B, is generally from 8 to 10 feet long, and should always be elastic, that it may yield to the oscillatory motion of the mill-stone. When its length is nine feet, and the weight of the equipage 5182 pounds, it should be six inches square; and when the length remains unchanged, and the equipage varies, the thickness of the bridge-tree should be proportional to the square root of the equipage.

Although the mechanism of a flour mill is exceedingly simple, the profitable manufacture of flour requires considerable experience and attention. We shall therefore give a sketch of the points most particularly to be attended to in such manufacture.

The wheats that grow in Essex and Kent make the best flour. In choosing the wheat much attention should be paid to the thinness of the skin and to its cleanliness from weed. Good wheat may be known by its weight, which should be about 62 pounds per Winchester bushel of 32 quarts. The wheat to be manufactured into the best flour should be winnowed.

The miller judges of the quality of the flour by feeling it, and accordingly as it is too fine or too coarse regulates the upper mill-stone, or increases or decreases the supply of grain. The flour in grinding always acquires a slight warmth, and care must be taken that the warmth does not increase, or the flour will be permanently injured.

The dressing of the flour is of great importance, and too much attention cannot be paid to it. The bran should be in large flakes and free of flour. In grinding the best wheats, in the best manner, the bran will amount to about seven pounds per bushel.

In the process of dressing, the bran is examined as a criterion to know whether too much flour be admitted upon the machine. Care should be taken to have the brush screwed close to the end of this machine.

French stones of about four feet in diameter are expected to grind about five bushels per hour.

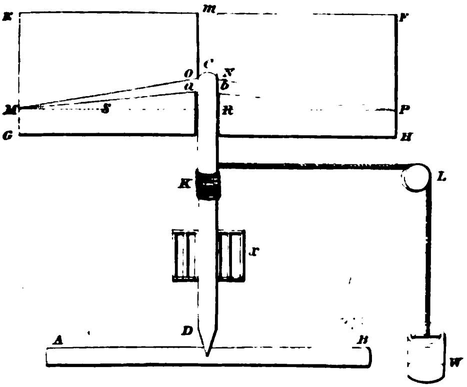
Mr Thomas Fenwick, the author of Four Essays on Practical Mechanics, has made numerous experiments on some of the best mills for grinding corn, in order to form, by practical observation, a set of tables illustrative of the effect of a given

Pl. 17.

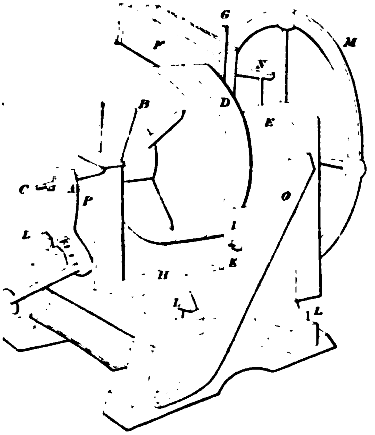
FLOUR MILLS.

From 156 to 160

156.p.146.



157.p.158.



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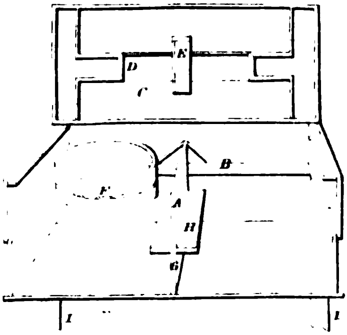

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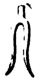

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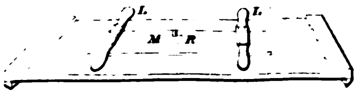


quantity of water, in a given time, applied to an overshot-wheel of a given size.

The quantity of water expended on the wheel was measured with great exactness: the corn used was in a medium state of dryness; the mills, in all their parts, were in a medium working state; the mill-stones, making from 90 to 100 revolutions per minute, were from 4½ to 5 feet in diameter.

The result of the experiments was, that the power requisite to raise a weight of 300 pounds avoirdupois, with a velocity of 190 feet per minute, would grind one boll of good rye in one hour; but for the sake of making the following tables hold in practice, where imperfection of construction exists in some small degree, he took it at 300 pounds raised with a velocity of 210 feet per minute, (being $\frac{1}{10}$th more,) and for grinding two, three, four, or five bolls per hour requires a power equal to that which could raise 300 pounds with the velocity of 350, 506, 677, or 865 feet per minute respectively. The difference of the power requisite to grind equal quantities of wheat to that for rye will be very trifling.

To enable the young mechanist to understand the application of his principles, he adds, as an illustration, that that number of horses, or other applied power, which, by means of a rope, (considered as without weight,) passing over a single pulley placed over the mouth of a pit or well, can raise out of it a load of 300 pounds avoirdupois, at the rate of 210 feet per minute, will be sufficient to grind one boll of corn per hour; and that a power which, in similar circumstances, can raise the same weight of 300 pounds with a velocity of 350 feet per minute, will be able to grind two bolls of corn per hour, and so on.

Having made some experiments to ascertain the friction of a mill, when going with a velocity sufficient to grind two bolls of corn per hour, he relates the manner in which he made them, that the reader may be able to judge of the accuracy of his deductions.

The mill was made quite clear of corn, and the upper mill-stone raised so that it would touch as little as possible on the under stone in its revolutions; then such a quantity of water was admitted to flow on the water-wheel, as to give the mill, when empty, the same velocity it had when grinding corn at the rate of two bolls per hour, which quantity of water was sufficient to raise a load of 300 pounds with a velocity of 100 feet per minute, which was therefore considered by him as the measure of the friction. Now as the power requisite to grind two bolls of corn per hour, including the friction of the mill, is equal to that which can raise a weight of 300 pounds with a velocity of 350 feet per minute, and the friction of the moving parts of the mill is equal to a power which would raise 300 pounds with a velocity of 100 feet per minute; therefore the difference of the two, which is 300 pounds raised with the velocity of 250 feet per minute, is equal to the power employed in the actual grinding of the corn, which is about two-thirds of the whole.

The power equal to raise a weight of 300 pounds avoirdupois, with a velocity of 390 feet per minute, will prepare properly one ton of old rope per week, for the purpose of making paper: and, for preparing in like manner, two tons of the same kind of materials per week, requires a power equal to raise 300 pounds with a velocity of 525 feet per minute, the mill working from 10 to 12 hours per day.

Tables, showing the quantity of water, (ale measure,) requisite to grind different quantities of corn, from one to five bolls, (Winchester measure,) per hour, applied on overshot water-wheels from 10 *to* 32 *feet diameter; also the size of the cylinder of the common steam-engine to do the same work.*

The water-wheel, 10 feet diameter.			The water-wheel, 11 feet diameter.		
Bolls of corn ground per hour.	Quantity of water requisite, in ale gallons, per minute.	Diameter of the cylinder of a steam engine to do the same work, in inches.	Bolls of corn ground per hour.	Quantity of water requisite, in ale gallons, per minute.	Diameter of the cylinder of a steam-engine to do the same work, in inches.
1	786	12.5	1	705	12.5
1½	1056	14.6	1½	945	14.6
2	1341	16.75	2	1188	16.75
2½	1617	18.5	2½	1454	18.5
3	1894	20.2	3	1723	20.2
3½	2220	21.75	3½	2014	21.75
4	2541	23.25	4	2306	23.25
4½	2891	24.75	4½	2626	24.75
5	3242	26.25	5	2944	26.25

The water wheel, 12 feet diameter.

Bolls of corn ground per hour.	Quantity of water requisite, in ale gallons, per minute.	Diameter of the cylinder of a steam-engine to do the same work, in inches.
1	655	12.5
1½	873	14.6
2	1091	16.75
2½	1343	18.5
3	1576	20.2
3½	1840	21.75
4	2117	23.25
4½	2408	24.75
5	2700	26.25

The water-wheel, 14 feet diameter.

Bolls of corn ground per hour.	Quantity of water requisite, in ale gallons, per minute.	Diameter of the cylinder of a steam-engine to do the same work, in inches.
1	564	12.5
1½	740	14.6
2	927	16.75
2½	1140	18.5
3	1353	20.2
3½	1583	21.75
4	1811	23.25
4½	2060	24.75
5	2306	26.25

The water-wheel, 13 feet diameter.

Bolls, per hour.	Water, gallons per minute.	Cylinder, in inches.
1	606	12.5
1½	806	14.6
2	1009	16.75
2½	1234	18.5
3	1458	20.2
3½	1705	21.75
4	1952	23.25
4½	2223	24.75
5	2494	26.25

The water-wheel, 15 feet diameter.

Bolls, per hour.	Water, gallons per minute.	Cylinder, in inches.
1	535	12.5
1½	710	14.6
2	894	16.75
2½	1090	18.5
3	1290	20.2
3½	1503	21.75
4	1717	23.25
4½	1967	24.75
5	2211	26.25

The water-wheel, 16 feet diameter.

Bolls of corn ground per hour.	Quantity of water requisite, in ale gallons, per minute.	Diameter of the cylinder of a steam-engine to do the same work, in inches.
1	491	12.5
1½	650	14.6
2	811	16.75
2½	993	18.5
3	1176	20.2
3½	1380	21.75
4	1582	23.25
4½	1802	24.75
5	2023	26.25

The water-wheel, 18 feet diameter.

Bolls of corn ground per hour.	Quantity of water requisite, in ale gallons, per minute.	Diameter of the cylinder of a steam-engine to do the same work, in inches.
1	410	12.5
1½	595	14.6
2	730	16.75
2½	860	18.5
3	1054	20.2
3½	1227	21.75
4	1400	23.25
4½	1600	24.75
5	1800	26.25

The water-wheel, 17 feet diameter.

Bolls, per hour.	Water, gallons per minute.	Cylinder, in inches.
1	458	12.5
1½	628	14.6
2	770	16.75
2½	943	18.5
3	1117	20.2
3½	1300	21.75
4	1482	23.25
4½	1695	24.75
5	1906	26.25

The water-wheel, 19 feet diameter.

Bolls, per hour.	Water, gallons per minute.	Cylinder, in inches.
1	411	12.5
1½	550	14.6
2	690	16.75
2½	845	18.5
3	1000	20.2
3½	1165	21.75
4	1330	23.25
4½	1517	24.75
5	1707	26.25

The water wheel, 20 feet diameter.

Bolls of corn ground per hour.	Quantity of water requisite, in ale gallons, per minute.	Diameter of the cylinder of a steam-engine to do the same work, in inches.
1	392	12.5
1½	530	14.6
2	675	16.75
2½	808	18.5
3	945	20.2
3½	1110	21.75
4	1270	23.25
4½	1445	24.75
5	1623	26.25

The water-wheel, 22 feet diameter.

Bolls of corn ground per hour.	Quantity of water requisite, in ale gallons, per minute.	Diameter of the cylinder of a steam-engine to do the same work, in inches.
1	350	12.5
1½	473	14.6
2	594	16.75
2½	722	18.5
3	860	20.2
3½	1007	21.75
4	1153	23.25
4½	1313	24.75
5	1472	26.25

The water-wheel, 21 feet diameter.

Bolls, per hour.	Water, gallons per minute.	Cylinder, in inches.
1	370	12.5
1½	500	14.6
2	635	16.75
2½	767	18.5
3	900	20.2
3½	1060	21.75
4	1212	23.25
4½	1379	24.75
5	1547	26.25

The water-wheel, 23 feet diameter.

Bolls, per hour.	Water, gallons per minute.	Cylinder, in inches.
1	338	12.5
1½	454	14.6
2	570	16.75
2½	707	18.5
3	824	20.2
3½	964	21.75
4	1124	23.25
4½	1258	24.75
5	1412	26.25

The water-wheel, 24 feet diameter.

Bolls of corn ground per hour.	Quantity of water requisite, in ale gallons, per minute.	Diameter of the cylinder of a steam-engine to do the same work, in inches.
1	327	12.5
1½	436	14.6
2	545	16.75
2½	671	18.5
3	788	20.2
3½	920	21.75
4	1050	23.25
4½	1204	24.75
5	1350	26.25

The water-wheel, 26 feet diameter.

Bolls of corn ground per hour.	Quantity of water requisite, in ale gallons, per minute.	Diameter of the cylinder of a steam-engine to do the same work, in inches.
1	303	12.5
1½	403	14.6
2	504	16.75
2½	617	18.5
3	730	20.2
3½	852	21.75
4	975	23.25
4½	1111	24.75
5	1247	26.25

The water-wheel, 25 feet diameter.

Bolls, per hour.	Water, gallons per minute.	Cylinder, in inches.
1	316	12.5
1½	418	14.6
2	520	16.75
2½	635	18.5
3	752	20.2
3½	876	21.75
4	985	23.25
4½	1150	24.75
5	1300	26.25

The water-wheel, 27 feet diameter.

Bolls, per hour.	Water, gallons per minute.	Cylinder, in inches.
1	293	12.5
1½	385	14.6
2	482	16.75
2½	593	18.5
3	703	20.2
3½	822	21.75
4	940	23.25
4½	1070	24.75
5	1200	26.25

The water-wheel, 28 feet diameter.

Bolls of corn ground per hour.	Quantity of water requisite, in ale gallons, per minute.	Diameter of the cylinder of a steam engine to do the same work, in inches.
1	282	12.5
1½	370	14.6
2	463	16.75
2½	570	18.5
3	676	20.2
3½	791	21.75
4	905	23.25
4½	1030	24.75
5	1153	26.25

The water-wheel, 29 feet diameter.

Bolls, per hour.	Water, gallons per minute.	Cylinder, in inches.
1	274	12.5
1½	363	14.6
2	455	16.75
2½	557	18.5
3	660	20.2
3½	770	21.75
4	880	23.25
4½	1005	24.75
5	1130	26.25

The water-wheel, 30 feet diameter.

Bolls of corn ground per hour.	Quantity of water requisite, in ale gallons, per minute.	Diameter of the cylinder of a steam-engine to do the same work, in inches.
1	267	12.5
1½	355	14.6
2	447	16.75
2½	545	18.5
3	645	20.2
3½	750	21.75
4	858	23.25
4½	983	24.75
5	1106	26.25

The water-wheel, 31 feet diameter.

Bolls, per hour.	Water, gallons per minute.	Cylinder, in inches.
1	256	12.5
1½	340	14.6
2	426	16.75
2½	520	18.5
3	620	20.2
3½	717	21.75
4	827	23.25
4½	940	24.75
5	1058	26.25

The water-wheel, 32 feet diameter.		
Bolls of corn ground per hour.	Quantity of water requisite, in ale gallons, per minute.	Diameter of the cylinder of a steam engine to do the same work, in inches.
1	245	12.5
1½	325	14.6
2	406	16.75
2½	496	18.5
3	588	20.2
3½	690	21.75
4	791	23.25
4½	900	24.75
5	1012	26.25

To make the foregoing tables applicable to mills intended to be turned by undershot or breast water-wheels: from Smeaton's experiments it appears that the power required on an undershot water-wheel, to produce an effect equal to that of an overshot, (to which the tables are applicable,) is as 2.4 to one; and also the power required on a breast water-wheel, which receives the water on some point of its circumference, and afterwards descends on the ladle boards, to produce an equal effect with an overshot water-wheel, is as 1.75 to 1.

A Table, showing the necessary size of the cylinder of the common steam-engine to grind different quantities of corn, from 1 *to* 12 *bolls,* (4 *to* 48 *bushels Winchester measure,) per hour.*

Bolls of corn ground per hour.	Diameter of the cylinder of a steam-engine to do the same work, in inches.
1	12.5
1½	14.6
2	16.75
2½	18.5
3	20.2
3½	21.75
4	23.25
4½	24.75
5	26.25
5½	27.25
6	28.1
6½	29.
7	29.8
7½	31.1
8	32.
8½	33.3
9	34.2
9½	35.2
10	36.
10½	37.3
11	38.
11½	38.85
12	39.5

N.B. This table will be applicable to any improved steam-engine, as well as that of the common kind, if the ratio of their efficacies be known.

APPLICATION OF THE TABLES.

Example I.—*If a stream of water, producing* 808 *gallons, ale measure, per minute, can be applied to an overshot water-wheel* 20 *feet diameter, what quantity of corn will it be able to grind per hour?*

Look in the tables under a 20 feet water-wheel, and opposite 808 gallons will be found 2½ bolls of corn ground per hour.

Example II.—*If a stream of water producing* 808 *gallons, ale measure, per minute, can be applied to an undershot water-wheel* 20 *feet diameter, what quantity of corn can it grind per hour?*

It is found by the tables, that, if applied on an overshot water-wheel 20 feet diameter, the stream will grind 2½ bolls per hour; and from page 156, the power required by the undershot to that of the overshot water-wheel, to produce an equal effect, is as 2.4 to 1; therefore, as 2.4 : 1 : 2.5 : 1.04 bolls of corn ground per hour by means of the stream.

Example III.—*If a stream of water, producing* 808 *gallons, ale measure, per minute, can be applied on a breast water-wheel* 20 *feet diameter, what quantity of corn can it grind per hour?*

It is found by the tables, that, if applied to an overshot water-wheel of equal size, 2½ bolls of corn will be ground per hour; and from page 156, the power of a breast water-wheel to that of an overshot water-wheel, to produce an equal effect, is as 1.75 to 1; therefore, as 1.75 : 1 : : 2.5 : 1.42 bolls of corn ground per hour by the stream.

Example IV.—*Of what diameter must the cylinder of a common steam-engine be made, to grind* 10 *bolls of corn per hour?*

By looking on the table, page 157, opposite 10 bolls ground per hour, the diameter of the steam cylinder will be found to be 36 inches.

FAMILY MILL AND BOLTER.

As a family mill and bolter cannot but be highly useful in many situations, we shall give a description of one or two, beginning with that invented by Mr T. Rustall, of Purbrook-heath, near Portsmouth, who received a premium of forty guineas from the Society of Arts for his invention.

In fig. 157, A is the handle of the mill; B one of the mill-stones, which is about 30 inches in diameter, and five inches in thickness, moving with its axis C; D is the other mill-stone, which, when in use, is stationary; but which may be placed near to or at a distance from the movable stone B, by means of three screws passing through the wooden block E, that supports one end of the axis C, after it has been put through a hole or perforation in the bed-stone. The grain likewise passes through this perforation, from the hopper F, into the mill. F represents the hopper, which is agitated by two iron pins on the axis C, that alternately raise the vessel containing the grain, which again sinks by its own weight. In consequence of this motion the corn is conveyed through a spout that passes from such hopper into the centre of the mill behind, and through the bed-stone D. G, a paddle, regulating the quantity of corn to be delivered to the mill, and by raising or lowering which, a larger or smaller proportion of grain may be furnished; H, the receptacle for the flour, into which it falls from the millstones, when ground; I represents one of the wooden supporters on which the bed-stone, D, rests. These are screwed to the block E, and likewise mortised into the lower frame-work of the mill at K, which is connected by means of the pins or wedges, L, L, L, that admit the whole mill to be easily taken to pieces; M, a fly-wheel, placed at the farthest extremity of the axis C, and on which another handle may be occasionally fixed; N, a small rail, serving to keep the hopper in its place, the furthest part of such hopper resting on a small pin, which admits of sufficient motion for that vessel to shake forward the corn; O, a spur-rail, for strengthening the frame-work of the mill; P, the front upright, that is mortised into the frame-work, and serves as a rest for the end of the iron axis C, which is next to the handle. On each extremity of such axis there is a shoulder, which keeps it steady in its place. Lastly, there is a cloth hood fixed to a broad wooden hoop, which is placed over the stones while working, to prevent the finer particles of flour from escaping.

Fig. 158 represents the bolter, with its front removed, in order to display its interior structure; the machine being 3 feet 10 inches in length, and 19½ inches in breadth, and 18 inches in depth. A is a movable partition, sliding about four feet backwards or forwards from the centre of the box, upon two wooden ribs, which are fixed on the back and front of the box, and one of which is delineated at the letter B; C, the lid of the bolter, represented open; D, a slider, which is movable in a groove made in the lid, by means of two handles in the back of such lid; E, a forked iron, fixed in the slider D, and which, when the lid is shut, takes hold of the sieve F, and moves it backwards and forwards on the wooden ribs B, according to the agitation of the slider; G represents a fixed partition in the lower centre of the box, which it divides into two parts, in order to separate the fine from the coarse flour; from this partition the slider A moves each way about four inches, and thus affords room for working the sieve; H a board that is parallel to the bottom of the bolter, and forms part of the slider A; this board serves to prevent any of the sifted matter from falling into the other partition; I represents two of the back feet which support the bolter.

Fig. 159 is a view of the top or upper part of the lid of the bolter; R the slider that moves the lengthwise of the bolter; L L the handles by which the slider is worked; M, a screw, serving to hold the fork, which imparts motion to the sieve.

Fig. 160 represents the forked iron, E, separately from the lid.

Both the mill and bolter may be constructed at a moderate expense, and they occupy only a small space of ground. The former may even be worked in a public kitchen, or within a room in a farm-house, without occasioning any great encumbrance.

The particular excellence of this mill consists in this circumstance, that, from the vertical position of its stones, it may be put in action without the intervention of cogs or wheels. It may be employed in the grinding of malt, the bruising of oats for horses, and for making flour, or for all these purposes: it likewise may be easily altered, so as to grind either of those articles to a greater or less degree of fineness.

Another advantage peculiar to Mr Rustall's contrivance is, that one man is sufficient to work it; though, if two persons, namely, a man and a boy, be employed, they will be able to produce, in the course of two hours, a quantity of flour sufficient to serve a family, consisting of six or eight person, for a whole week:—repeated satisfactory trials have proved that this mill grinds the corn completely, and at the rate of one bushel of wheat within the hour. Besides, the industrious farmer will thus be enabled to make comparative experiments on the quality of his grain, and may furnish himself, at a trifling expense, with flour from his own wheat, without apprehending any adulteration, or without being exposed to the impositions or caprice of fraudulent and avaricious millers.

Lastly, though Mr Rustall's bolter be more particularly calculated for sifting flour, it may also be applied to various other useful purposes, and especially with a view to obviate the inconveniences necessarily attendant on the levigation of noxious substances, and to prevent the waste of their finer particles.

In order to reduce the labour in grinding, and to adjust the pôwer to the acquired force, and also to simplify mill-making and grinding, and to reduce the expense attendant upon them, so as to enable the farmer and housekeeper to be independent of the miller's system of grinding, Mr George Smart, of the Ordnance-wharf, Westminster-bridge, in April 1814, obtained a patent for certain improvements in machinery for grinding corn, and various other articles, by means of which every article required to be broke or ground is exposed to the application of rubbers or crushers, resting on their fulcrums, and pressed against the revolving body by means of levers, weights, or springs. The rubbers, or crushers, each acting on a separate axle, will admit of any irregular surface, from a square to a circle, to revolve against them, as each can be loaded more or less, by moving the weight on the levers further from, or nearer to, the fulcrum; or, if with springs, by screwing them more or less down. The rubbers or crushers may be plain, grooved, circular-sided, concave, or any other figure best adapted for the substance to be broke or ground. The square or octagon are best adapted for breaking cement-stones, bones for manure, chalk, mixing clay, mortar, &c. For breaking malt, beans, &c. one crusher only is wanted; but for wheat, oats, barley, rice, or any flour, or meal, the more rubbers or crushers the finer the article will be ground; and the more flats there are on the revolving body, the more crushers can be applied to advantage.

HAND-MILLS

Are most commonly used in grinding coffee and spices; but they are sometimes made of a larger size, and used to grind wheat, malt, &c.; in such cases the hand is generally applied to a winch handle. In Bockler's *Theatrum Machinarum* there is a description of a mill, in which the effort of a man is applied to a lever moving to and fro horizontally, nearly as in the action of rowing: as this is a very advantageous method of applying human strength, the effort being greatly assisted by the heaviness of the man in leaning back, we shall give a brief description of it.

It is represented in fig. 161. The vertical shaft E G carries a toothed wheel C, and a solid wheel F; the latter being intended to operate as a regulating fly. Upon the crank A B hangs one end of an iron I, the other end of which hangs upon the lever H K, the motion being pretty free at both ends of this bar I. One end of the lever H K, hangs upon the fixed hook K, about which, as a centre of motion, it turns. Then, while a man, by pulling at the lever H K, moves the extremity H from H to N, the bar I acting upon the crank A B gives to the wheels C and F half a rotation; and the momentum they have acquired will carry them on, the man at the lever suffering it to turn back from N to H, while the other half of the rotation of the wheels is completed. In like manner another sufficient pull at the lever H K gives another rotation to the wheel C, and so on, at pleasure. The wheel C turns by its teeth the trundle D, the spindle of which carries the upper mill-stone, just as the spindle D carries round the upper mill-stone, in fig. 156. In this mill the nearer the end of the bar I upon the lever H K is to the fixed hook K, the easier, *cæteris paribus*, will the man work the mill. If the number of teeth in the wheel C be six times the number of cogs in the trundle D, then the labourer, by making ten pulls at the lever H in a minute, will give sixty revolutions to the upper mill-stone in the same space of time.

In the *Transactions of the Society of Arts* may be seen a description of a mill, invented by Mr Garnett Terry, of the City-road, for grinding hard substances, by means of a wheel turning upon a horizontal axis instead of a vertical one, as in the common construction. See fig. 162.

THE FOOT-MILL

Is used for grinding corn or any other substance, moved by the pressure of the feet of men or oxen. A judicious construction of the foot-mill is given in G. A. Bockler's *Theatrum Machinarum*.

This mill is represented in fig. 163. A is an inclined wheel, which is turned by the weight of a man, and the impulsive force of his feet while he supports himself, or occasionally pushes with his hands at the horizontal bar H. The face of this wheel has thin pieces of wood nailed upon it at proper distances, to keep the feet of the man from slipping while he pushes the wheel round: and the under side has projecting teeth or waves which catch into the cogs of the trundle B, and by that means turn the horizontal shaft G with the wheel C: this latter wheel turns the trundle D, the axle of which carries the upper mill-stone E. This kind of foot-mill will answer extremely well to grind malt, &c. when no very great power is required.

KNEADING-MILL.

The business of grinding and baking is in one sense so closely connected, that we shall in this place present a description of the kneading-mill; which is meant to do away with that disgusting practice among bakers of kneading the dough with their bare feet. It would be well if the legislature paid some attention to this, which is still carried on in some parts of the metropolis, and particularly in the kneading of dough for biscuits.

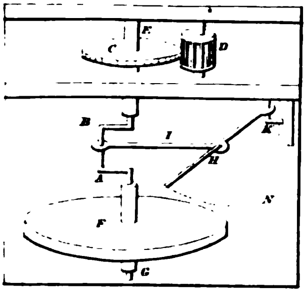
In the public baking-houses of Genoa a machine is used which produces a great saving of time and labour. It was first described in the *Atti della Societa Patriotica di Milano*, vol. ii.

A, in fig. 164, is a frame of wood which supports the axis of the machine: a wall 14 palms high from the ground may be made use of instead of this frame. B, a wall, 3½ palms thick, through which the aforesaid axis passes. C, another wall similar to the former, and facing it at the distance of 21 palms. D, the axis, 30 palms in length, and one palm and one-third in thickness. E, the great wheel, fixed to the said axis between the frame and the wall; its diameter is 28 palms; and its breadth, which is capable of holding two men occasionally, is five palms. F, are steps, by treading on which the men turn the wheel very smartly; they are two palms distant from each other, and one-third of a palm in height. G, a small wheel with cogs, fixed almost at the further extremity of the axis: its diameter is 12¼ palms. H, a beam of wood which extends from one wall to the other, being 21 palms in length, and one and a third in thickness. A similar beam, not seen in the figure, is on the opposite side of the axis. I, a transverse piece of wood, placed near the wall C; it is fixed into the two beams, and serves to support the further extremity of the axis; its length is 14 palms, and its thickness one and a third: there is likewise a transverse piece, (which cannot be seen in the figure,) 14 palms long, and half a palm thick, placed close to the wall B. K is a strong curved piece of oak, fixed transversely in the side beams H, to receive the axis of the trundle: its length is 14 palms, and its thickness 1½. L is a trundle of 5½ palms in diameter, and 1¼ in height, which is moved by the cog-wheel G. M is a trundle proceeding from the trundle L, and continued through the cross N to the bottom of the tub P; its centre is made of iron, partly square and partly round, and it turns in a socket of brass. The first part of this axis between the trundle L and the cross N is of square iron, surrounded by two pieces of wood, held together by iron hoops, which may be removed at pleasure to examine the iron within; its length is three palms, its diameter about one palm. The second part of the axis which is within the tube, is made like the first part: its length is 1½ palm, its diameter one and one-sixth. The wooden sheath of this part of the axis is fixed to the bottom of the tub, by the means of three screws with their nuts. This axis is distant one-third of a palm from the nearest triangular *beater* of the cross. N, the cross, formed of two bars of wood unequally divided, so that the four arms of the cross are of different lengths: one of the two pieces of wood of which the cross is made is six palms in length, the other five; their thickness is seven-twelfths of a palm,

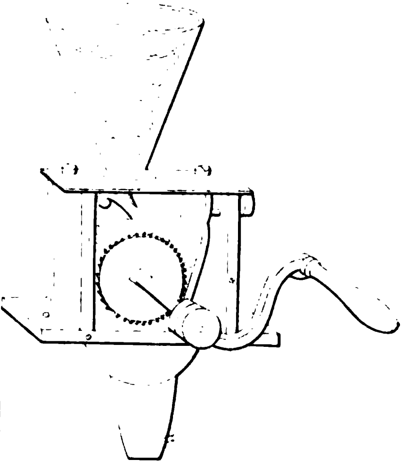
FLOUR MILLS.

From 161 to 167

161.p.161.



162.p.161.



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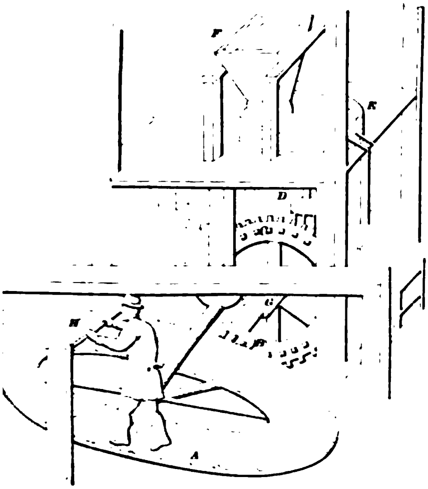
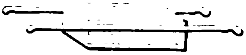


165.p.163.



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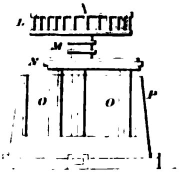
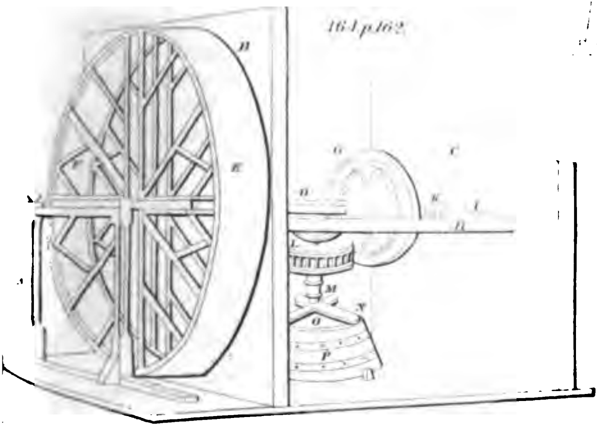
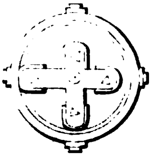


164.p.162.



167.p.163.



and their breadth one palm. O, four pieces of wood, called *beaters*, of a triangular shape, fixed vertically into the extremities of, and underneath, the arms of the fore-mentioned cross; they are 1¾ palm in length, and half a palm in thickness, and beat or knead the dough in the tub at unequal distances from the centre. P is a stout wooden tub, about a quarter of a palm thick, well hooped with iron; its diameter is six palms, its height 1½ in the clear. Fig. 165 is a box or trough of wood, four palms long, and three wide, in which the leaven is formed, (in about an hour,) in a stove, and in which it is afterwards carried to the tub P. Fig. 166 exhibits a view of the trundle, cross, &c. with a section of the tub. Fig. 167 is a bird's-eye view of the cross and tub, with the upper ends of triangular beaters. This tub P will contain about 18 rubbi (about 19 bushels) of flour, which is carried to it in barrels: the leaven is then carried to it in the box or trough, and when the whole is tempered with a proper quantity of warm water, the men work in the wheel till the dough is properly and completely kneaded. In general a quarter of an hour is sufficient to make very good dough; but an experienced baker, who superintends, determines that the operation shall be continued a few minutes more or less, according to circumstances.

The measures in the preceding description are given in Genoese palms, each of which is very nearly equal to 9.85 of our inches. The machinery may be varied in its construction according to circumstances, and the energy of the first mover much better applied than by men walking in a common wheel.

In November 1811, a patent was granted to Mr Joseph Baker, navy contractor, for a method of kneading dough by means of machinery. The invention consists in having an upright shaft, turning on a pivot, fixed in the centre of a circular trough, so that the dough placed in such trough may be kneaded by a stone or iron roller, on its edge, passing over it in a rotatory motion, being fixed at a due distance by an horizontal bar or axle to the shaft, which is to be turned by means of one or more other horizontal bars likewise fixed thereto, and worked like a capstan by a proportionate number of bipeds or quadrupeds, such horizontal bars having small shares fixed to them, so as to run in the trough, and, acting like a plough, cause the dough to present fresh surfaces for each successive revolution.

Independent of the methods above quoted, many others might easily be adapted, to do away with the filthy practice to which we have alluded.

THE STEAM-ENGINE.

The most prominent feature in modern discovery is the *steam-engine*, which has, with much propriety, been denominated "the noblest monument of human ingenuity." The Marquis of Worcester, who lived in the reign of Charles II. is entitled to the honour of having first directed the attention of mankind to the expansive force of steam when used in a close vessel: but in the book published by him in 1663, he is not sufficiently explicit or intelligible for us to determine what kind of apparatus, or combination of machinery, was used by him for the guidance of its powers. It is however but reasonable to suppose, notwithstanding the vagueness of his expressions, that it was principally owing to the direction his observations gave to the minds of others that steam began to be used as the first mover of machinery.

When water is exposed to the action of heat, it expands and assumes the gaseous state called steam. When it is confined in a close vessel, and heat is applied to it, the quality of expansion is exerted to a powerful extent; and as the space between the top of the water and the top of the vessel is filled with atmospheric air, the first portion of the power, exerted by the expansion of the steam, is directed towards the displacing of that atmosphere from the situation which its weight had assigned it, and, consequently, such portion of the direct action of the expansive force of steam is to be deducted from its disposable power. This portion of power is, however, ultimately available. For as by a reduction of temperature steam reassumes the state of water, leaving the space which it had occupied again void, the atmosphere which it had displaced returns to its former situation, exerting a force, so to do, exactly tantamount to that which the steam had exerted to displace it. This force may be termed the consequent power of steam. The directing and controlling of these powers, so that they may be applied to the purpose of creating equable motion, is the object attained almost to perfection in the steam-engine: and it is the more accurate control, the more advantageous application, and the more economic production of these powers, that have been aimed at in its various modifications.

For more perfectly illustrating the mode in which steam operates, we will suppose the vessel, represented at fig. 168, to be filled with water up to the line A, and the space E occupied with air, and having a plug or piston fitting it at C, and an aperture at D; now if the aperture D be closed, and heat applied to the water, as at F, steam will be generated, and by its expansive force will raise the piston C upwards; then if the heat be withdrawn and the vessel suddenly cooled, condensation will take place; the steam, reassuming the form of water, will again occupy the space below the line A, and the piston C will return to its place. In this experiment the expansive force of the steam compressed the air in the space E, and forced the plug C upwards, we will suppose, to H; but C, in travelling to H, displaced so much of the atmosphere as occupied the tube from C to H; consequently, the portion so displaced will seek to resume its natural position, and when the force of the steam is withdrawn by condensation, the weight of that portion of the atmosphere will again return the plug C to its place; by which, it is obvious, that the raising of the plug was the direct action of the steam, and the returning its consequent action, or the action of the atmosphere in consequence of its having been displaced by the force of the steam.

Again, if we suppose the plug to be in its first situation, as at C, and we open the aperture at D, and apply heat, the steam will rise into the space E, and expel the air through the aperture D, which being closed, and condensation caused, the space E will be left a vacuum, and the atmosphere seeking to occupy that space will force the plug C down to the line A; here the movement of the plug C was solely caused by the atmosphere exerting itself to regain the position whence it had been expelled by the force of the steam through D, and this effect is performed by the consequent power of steam alone.

It has been found by experiments, that the pressure of the atmosphere is equal to about 14 pounds weight upon every square inch, so that supposing the superficies of the aperture of the vessel, fig. 168, to contain one square inch, the power exerted by the steam in raising C to H will be tantamount to raising 14 pounds weight that height, together with the power necessary to overcome the friction and weight of the piston C, in the cylinder; and, that the power exerted by the steam in expelling the atmosphere from the space E, and obtaining its consequent pressure to the raising of 14 pounds from A to C; and that the disposable power, obtained by the return of the piston from H, will, in the first instance, be equal to the raising of 14 pounds weight from C to H, less the amount of the friction of the piston C; and, in the second, will be equal to the raising of 14 pounds weight from C to A, less the amount of the friction as before. In both these instances the expansive or direct force of the steam has only been considered as equal to the displacing of the atmosphere, or what will be equal to 14 pounds pressure on each superficial inch; but if the piston C be loaded with any weight, the steam will, if urged with sufficient heat, raise it, always premising that the vessel is strong enough to resist the increased pressure. Suppose C to be loaded with 10 pounds of weight, the steam must be urged until its pressure is equal to 24 pounds, 10 pounds more, 14 pounds the pressure of the atmosphere on each square inch, and the resulting disposable force will be equal to 24 pounds more, the weight of C, less its friction returning to the place from where C was raised; so that, in this case, the pressure on the internal sides of the vessel, tending to burst it, will be equal to 10 pounds per square inch of the internal superficies, the remaining 14 pounds being counteracted by the pressure of the atmosphere on the external surface, which is equal to 14 pounds of the internal pressure. By this, it is evident, that the direct force of steam may be increased without limits, whereas the resulting force or pressure of the atmosphere is manifestly bounded to 14 or 15 pounds on the square inch, according as its density varies.

Trusting from this explanation that even those who are unacquainted with matters of this nature will clearly comprehend the manner in which the expansive force of steam operates, we shall proceed to explain the different mechanical combinations which have been formed to render this power subservient to our will: premising that what we have heretofore called the consequent power of steam will, in future, be considered the pressure of the atmosphere, which in fact it is, having adopted the other term in the introductory explanation, in order more clearly to impress on the mind, that the expansive force of steam is actually the only originator of power in this machine.

The first apparatus with which we are acquainted, constructed for the purpose of employing steam as power to act in a close vessel, was invented by a Captain Savary, for which, in the year 1698, he obtained a patent. The form of it, as invented by him, is represented in fig. 169.

a, a close boiler, placed on a furnace, and of sufficient strength to resist considerable pressure; B another vessel strongly constructed; *c c* a pipe with a cock in it at *i*, by means of which a communication can be made from *a* to B at pleasure; *e* a pipe proceeding downwards into a well or other reservoir of water; *f f* another pipe proceeding from B to a reservoir placed above; *h h* is a pipe communicating from B to the pipe *f f*, and having a cock in it at *k* to allow of, or cut off, such communication; *m* is a valve capable of closing the pipe *e* by pressure from above, and of opening it by pressure from below; *l* a similar valve fitted to the pipe *f f*, and capable of being acted upon in a similar manner. If the boiler *a* be filled with water to the dotted line, and heat applied by means of the furnace, the steam will rise in the boiler, and passing through the pipe *c c*, fill the vessel B, and pass up the pipe *f f*; the valve *m* being shut by the expansive force of the steam pressing upon it: if the cock *i* be now shut and the steam in the vessel B condensed, by throwing cold water upon its outer surface, the atmosphere pressing on the valve *m* will close it, and the interior of the vessel B remain a vacuum, and the water in the reservoir to which the pipe *e* passes will be forced by the external pressure of the atmosphere into the vessel B up to the dotted line, which is supposed to be about 26 feet from the surface of the water in the reservoir, being the length of a column of water, which, taking into account that the vacuum thus formed is not quite perfect, is equal to the pressure that will be exerted by the atmosphere. If the cock *i* be opened again, and the steam allowed to press on the surface of the water, in B, it will close the valve *m*, and cause the water to ascend the pipe *f f*, through the valve *l*, to the upper reservoir; and when the cock *i* is again shut, and the steam in B again caused to condense, the operation will be repeated, and the weight of the water in the pipe *f f* will close the valve *l*, and cause the vessel B to be filled by *e* as before.

Such was the construction and mode of operating with the first apparatus made by Captain Savary. But he, finding it inconvenient to cause condensation by means of throwing cold water upon the outer surface, introduced the pipe *h h* into B, which, by opening the cock *k*, allowed some portion of the water to pass from the pipe *f f*, which was always full after the first stroke, and thereby cause condensation more quickly to ensue.

The trial or gauge cocks *o*, *q*, were also contrived by Captain Savary, in order to ascertain the height of the water in the boiler. If the surface of the water is above the lower ends of the cocks, and the cocks be opened, water will issue from them, if below, steam. But if the water is at its proper level, that is to say, if the surface of the water be in the intermediate space between the ends of the cocks *q* and *n o*, water will issue from the former, and steam from the latter. This knowledge was necessary to be obtained; for should the surface of the water exceed the height of the cocks *o*, there will not be room for a sufficiency of steam to remain in store for continued operation.

The application of this engine was confined to the raising of water to small heights, as it operated only by atmospheric pressure; in deep mines it was found not to be effective. Taking into consideration, however, the then imperfect state of knowledge, so far as regarded steam as a first mover, the inventor is entitled to no inconsiderable degree of praise for this specimen of his ingenuity. The greatest objection to this mode is, the great waste of steam, and consequent unnecessary expenditure of fuel, arising from the condensation being effected by allowing cold water to come into contact with the steam in the vessel B.

At the time when the existence of this engine was first made known to the public, the amazing power of steam, which it so plainly demonstrated, began very deservedly to obtain the attention of ingenious men; and disputes for the honour of the discovery took place, the English ascribing it to the Marquis of Worcester, the French to Papin.

Without entering into the minutiæ of this contest, it will be sufficient for us to trace progressively the grand improvements that have taken place in the steam-engine in this country: though not forgetting to mention the accessary improvements derived from foreign aid. Of this latter is the safety valve, an instrument, though in itself simple, of such vast importance, that to it may be attributed the general introduction, and consequent improvement, of the steam-engine to its present existing state of perfection. It was contrived by Dr Papin, who at the time of Captain Savary's invention, was making experiments on the power of steam at high temperatures, for the purpose of dissolving bodies. It consists merely of an aperture of a specific dimension, suppose, for instance, one square inch, in or communicating with any close boiler, and a valve properly fitted in that aperture, such valve being on the outside loaded to any extent considered necessary to resist the force of the steam until it has acquired a certain degree of power, computed to be what the boiler is perfectly capable of sustaining without the chance of bursting. Now it is manifest, until the pressure of the steam within has exerted itself so far as to raise such weight, the internal pressure per square inch, tending to burst the boiler, does not exceed the amount of such weight, so that, by this means, an estimate of the chances of such an occurrence taking place can easily be made.

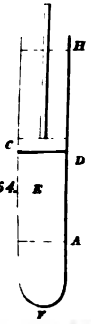
The contrivance of Dr Papin, of placing a piece of wood to float upon the surface of the water, though an improvement in this stage of the engine, is now of no importance : but it is not improbable, that this first suggested the idea of a close fitted piston working in a cylinder, which constituted the most valuable part in the next step of advancement. This was effected by an ironmonger or smith of the name of Newcomen, and a glazier of the name of Cauly, residing at Dartmouth, in Devonshire, who were contented to share the profits of the invention with Savary, and jointly with him obtained a patent for it in the year 1705.

This engine, generally called Newcomen's engine, was the first that had a piston fitted to work in a cylinder, which, together with the beam, gave to the construction of the machine a new character.

An engine upon this construction is represented in fig. 170, where A is a boiler placed upon a furnace; B, a cylinder, bored true, and having the piston *c* fitted to work easily therein; *q*, a cock in the pipe forming a communication from the boiler to the lower part of the cylinder; S, a safety valve loaded by the weight at the extremity of the lever *r t*, pressing upon the upright pin of the valve at *s*; *d d*, a pipe leading from the cylinder B to the reservoir *i*, with the cock *e* for opening and closing the connection; *f f*, another pipe leading also from the cylinder to the reservoir *h*, having a valve at the lower extremity, opening outwards, for the purpose of allowing any accumulation of condensed water in the cylinder to run off, and through which the air may be ejected by the steam when filling B; L L is a beam, supported upon the wall K K, and capable of vibrating upon the centre U; *a* is the rod of the piston, fastened to the curved end of the beam by a chain ; *m m* the rod of the pump, fixed to the beam in a manner similar to the piston rod; the pump is placed in the well or pit *x*, with the weights *o o* hanging upon the pump rods sufficient to counterbalance the piston and rod on the other end of the beam, and keep it raised to the top of the cylinder; *p p* is a pipe leading from the pump in the well to supply the cistern *i*.

Supposing the piston *c* to be in the situation c^1, near the top of the cylinder, and the steam in the boiler to be urged by fire in the furnace, and the cock *q* to be open, the cylinder B will become filled with steam, and the air that is in it be expelled by the pipe *f f*, and through the clack-valve at the end, which, from the noise made by such expulsion is called the snifting-clack. If the cock *q* be closed, and that at *e* opened, water will rush from the reservoir *i* into the cylinder, and by causing an immediate condensation of the steam create a vacuum, so that the pressure of the atmosphere will operate upon and force down the piston *c* to the bottom of the cylinder, and cause the other end of the beam L to rise as much as that end falls, which makes one stroke of the pump-rods. If the cock *e* be now closed, and *q* opened, steam will force against the bottom of *c*, and by

From 168 to 173



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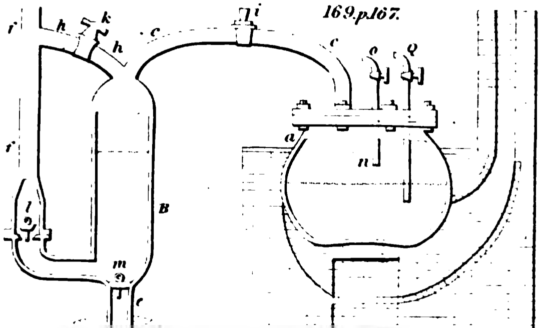

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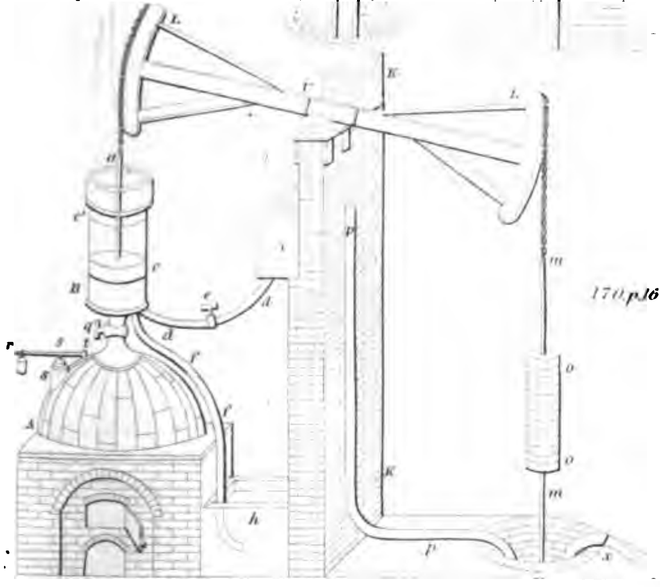

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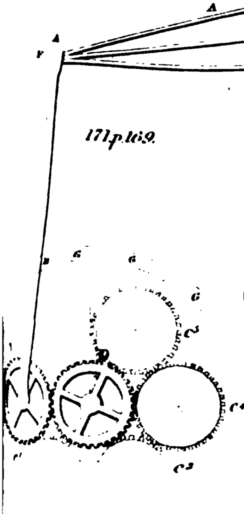

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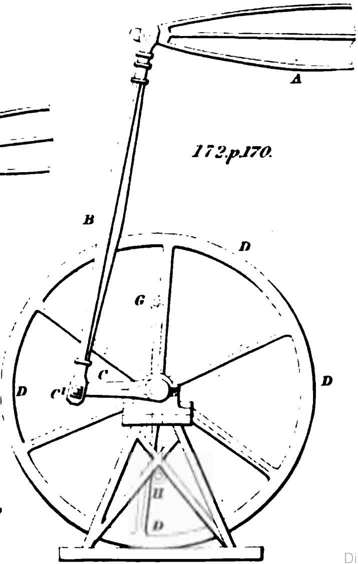

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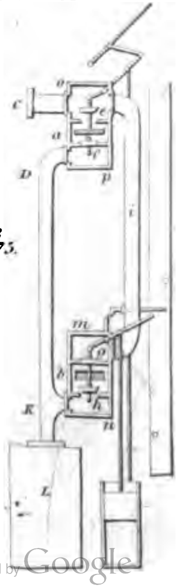


173
p.175.

overcoming the pressure of the atmosphere again raise it to its original position; and *q* being again closed, and *e* opened, the performance of a similar operation will be effected.

The advantage sought in the construction of this sort of engine was obtained, namely, that of not being required to use steam of greater pressure than the atmosphere, which was the case in Savary's engine, when the height the water was to be raised by the pipe *f f*, fig. 169, exceeded more than about 32 feet. In Newcomen's engine, the weight *o o* balances the piston *c*, and the exertion of the steam is never required to be more than about 14 pounds to the superficial inch; whilst the introduction of the beam affords a movement applicable to the working of pumps, by which water can be raised to any required height.

The cocks *q* and *e* were opened by the hand of an attendant until a boy of the name of Potter, who was intrusted with the management of them, to save himself the labour and attention which they required, ingeniously contrived to attach a piece of string to the levers of the cocks, and to the beam L L, in such a manner, as to procure by its movement their being opened and shut at the proper periods. It was this gave the idea for the construction of that part of the present engine called hand-geer.

The next person who made any considerable improvement in the steam-engine was Mr Henry Beighton, of Newcastle, who invented the part called the plug-tree, for opening and shutting the valves, which we shall describe in a more advanced part of the work: he also adopted a force-pump, to supply the deficiency of water in the boiler caused by the expenditure in the production of steam. This engine, called *Beighton's fire-engine*, was much used for nearly half a century; and the attention of engineers was directed more towards the economizing of fuel, than the further improvement of the engine.

At length, however, it began to be perceived, that the attainment of a rotatory motion would open an extensive field for the application of its powers to various mechanical purposes; and, accordingly, we find the attention of engineers most actively engaged in endeavouring to effect so desirable an object, which was eventually accomplished by Mr Matthew Washbrough, of Bristol, who, in the year 1778, obtained a patent for the application of the crank. Though this is by far the best application that has been yet applied, as is evident from its now almost universal adoption, it was for some time superseded by the sun and planet wheels introduced by Messrs Boulton and Watt.

The sun and planet wheels are represented in fig. 171. A represents the end of the beam, to which is affixed, by a movable centre at F, the rod B, called the connecting rod, upon the lower end of which is immovably fixed the wheel C; D is a cog-wheel, fixed upon the the axis of the fly-wheel G G G G, and capable of revolving with it. When the beam A passes downwards, the wheel C changes from its position at C to C 1, and its cogs, acting upon those of the wheel D, cause that, and the fly-wheel to which it is attached, to perform that portion of a revolution round its axis. The wheel C, from the manner in which it is suspended, tends always to press against D in its downward and upward motions. When C is in the position of C^2, the wheel D, from the velocity it has acquired by its connection with the fly-wheel, causes it to pass under the centre of D, and the beam beginning immediately to ascend, operates by C on the other side of D, giving it another portion of impulse towards a continuous motion whilst passing from C^3 to C^4, and when it arrives at C^5 it will be impelled over the centre D D by the velocity which its own action had given the fly-wheel.

The crank and fly-wheel invented by Mr Matthew Washbrough is shown in fig. 172. A and B represent the same parts as in fig. 171, but the lower end of B is, in this case, attached to the crank C at c^1, and is capable of revolving round the centre E; the other end of the crank is attached to the fly-wheel D D D D, so that both that and the fly-wheel are capable of revolving round the centre E. When the beam A is depressed, it communicates motion to the crank and fly-wheel to which it is attached, and when it arrives at H, the velocity of the fly-wheel causes it to pass under the centre E, and the beam beginning immediately to ascend, again communicates motion to the fly-wheel.

The length of the connecting rod B should be such that when the beam A is in an horizontal position, the crank will likewise be the same; and when the crank is in the position as at G, its length, together with the length of the crank, such as to permit the other end of the beam, A, to descend until the piston which is attached to it is at the bottom of the cylinder; and the length of these and the cylinder such, that when the crank is in the position H, the piston shall be at the top of the cylinder. This method not only affords a rotative motion, but determines the length of the stroke which the piston may be required to perform, to an exactness that is of great importance; for prior to its introduction, the forcible striking of the piston against the top and bottom of the cylinder, which was attended with injurious effects, was an occurrence by no means unfrequent, and which the sun and planet wheels were in no way calculated to remedy.

Mr Watt, a native of Glasgow, having his attention accidentally directed to the construction of the steam-engine, discovered that water, when confined in a close vessel, and heated considerably beyond the boiling temperature, would, when the steam was permitted to escape, cool rapidly down to the boiling point, which suggested an idea, that the amount of steam issuing from any vessel was simply in proportion to the amount of heat applied, and that the economizing of fuel could only be obtained by the economizing of steam. Mr Watt also noticed the great change which took place in the temperature of the cylinder when the cold water was injected to condense the steam; and concluded, that as the coldness of the cylinder would remain after the necessary condensation had been effected, a wasteful condensation of the newly introduced steam must take place. By experiment he found, that the quantity of steam thus wasted was no less than thrice the contents of the cylinder, or three times the quantity which was required for producing the effect sought. The modes to which he had recourse to remedy this defect were first, the substitution of a wooden cylinder, which, upon repeated trials, he was compelled to abandon, on account of the roughness produced by wet and the changes of temperature; secondly, the enclosing of the cylinder with wood, and filling the intermediate space with powdered charcoal; which afterwards was superseded by the introduction of an extra cylinder, that enclosed the working cylinder, and permitted steam to flow round it, which maintained it at a regular temperature. The outer cylinder is termed a jacket, and is now used with advantage.

In the year 1763, Mr Watt made the grand improvement of effecting the condensation in a separate vessel, communicating only by a pipe to the cylinder, termed the condenser.

In fig. 173, A is the lower part of the cylinder; B the condenser; C the eduction pipe, or pipe of communication between the cylinder and condenser, capable of being opened or closed by the cock *c*; and D D a chamber of cold water, in which the condenser B is immersed. When the cock *c* is opened, the steam, by its elastic force, rushes into B, where it is condensed; and the space it has left in the cylinder allows a new supply of steam to be generated, which, by the opening of the cock *c*, also passes into B, and is similarly condensed. The condensing of the steam necessarily accumulates water in B, and reduces the capacity of the condenser; to remedy which, Mr Watt introduced a small pump, worked by the engine, to withdraw the extra water, as also the air, which in some degree hindered the perfectness of the vacuum: he named it the *air-pump*. He also found it expedient to permit a small stream of water to run from the chamber D D, by means of a cock, which could regulate the supply according to the temperature of the water in D, or the required rapidity of the condensation. The cistern in which the condenser is placed is called the *cold-water cistern*; it is continually being supplied with fresh water from a pump connected with a well or pit, and the overplus is discharged by a spout into a drain. The hot water drawn from the condenser by the air-pump is delivered into another cistern, termed the *hot-water cistern*.

These parts are represented in fig. 174, where their distribution is such as to exhibit them conveniently, without taking into view their construction in any particular engine, as their form and relative possession is of no importance, and is arbitrarily varied as the different builders think fit, or as conveniency or circumstances may in many cases require. A is the cylinder; B the condenser; C the air-pump; E E the cold-water cistern; F the cold-water pump for supplying the same; S S the steam pipe from the boiler; H the eduction pipe from the cylinder to the condenser; O O the hot-water cistern; N the injection cock for allowing a small stream of water to flow into B; P the hot-water pump, which forces a sufficiency of water from the hot-water cistern through the pipe *q* to keep up the supply in the boiler; *t t t* are pump rods, fixed to the beam and worked by its motion; *g* is a suction pipe; and m the foot-valve. The pipe I and the valve V, opening upwards, are for the purpose of permitting the steam to pass through to expel the atmosphere from the condenser, called a blow-valve, and then by its own condensation to leave a vacuum on the starting of the engine.

A communication is made from the condenser by a pipe to the upper part of a tube standing in a bason of mercury. The amount of mercury in the tube will indicate the perfectness of the vacuum in the condenser, by exhibiting the height at which it is supported by the pressure of the atmosphere. If the vacuum is perfect, the mercury will stand from 28 to 31 inches.

The only difference between the working of this engine and those already described is, that the pipe H H, instead of being an injection pipe for the admission of cold water to the cylinder, merely leads off the steam to the condenser B, therefore, when condensation is to be effected, the cock *h* is opened to admit the steam from the cylinder into B, there to become condensed, whilst the continued action of the pump C maintains a vacuum in B, by drawing off the condensed water and the air. The cold-water pump F keeps up an abundant supply in the cistern E E, and the superplus is discharged at W; thus maintaining a depression of temperature sufficient to procure condensation in B.

Such was the importance of this alteration in the mode of construction, that one-half the quantity of fuel consumed by an engine of the former construction was saved. Still, however, the engine was not complete; the piston was required to have water kept upon its upper surface to keep it airtight, and as this, in the descent, cooled the cylinder considerably, it was, as is evident from what has been already stated, when speaking of the former mode of injecting cold water, productive of a loss, to which Mr Watt turned his serious attention, and eventually succeeded in remedying the evil.

The next construction of the engine is what is now called the single acting engine, and as the improvement consisted merely in the cylinder, a diagram of that will be sufficient to make it clearly understood. Finding, as has been stated, the disadvantages attending the open-ended cylinder, Mr Watt conceived the idea of closing the top of the cylinder, and of causing the piston-rod to work through a close collar stuffed with hemp and grease; and instead of making use of water to procure the piston working air-tight, of using oil or fat as a substitute; and instead of causing it to descend by the pressure of the atmosphere, of employing steam of an expansive force equal to that pressure.

In reference to fig. 175, A is the cylinder; B the piston; C C the stuffing-box filled with hemp moistened with tallow, having its cap screwed firmly down by two screws, so as to form a steam-tight joint round the piston-rod. The piston-rod being turned true and polished, is capable of working up and down through the steam-tight joint. D is the steam pipe leading from the boiler; K the eduction pipe leading to the condenser; H and I are two valves upon the rod L, which passes through stuffing boxes or steam-tight joints, at *m n*. While raising and lowering the rod L, the valves H and I open or close their respective apertures D and K. *g* is a valve which affords, when open, a communication between the top and bottom of the cylinder through the pipe P E, and from thence through O. Its spindle, which is hollow, works in a steam-tight collar at N, and has the rod L passing through it, likewise steam-tight, in such a manner that the rod L, with its valves, may be moved independent of the valve *g*, or the valve *g* independent of the rod L. If the valves are placed as represented, I and H open, and *g* shut, and the steam be permitted to come from the boiler through D, it will pass through H, and enter the top of the cylinder at P, depressing the piston B by its elastic force, whilst the lower part of the cylinder is open through O and K to the condenser. When the piston is depressed to B 1, the rod L must be moved downwards, and the valves H and I closed, and the valve *g* opened, that the steam, by its elastic force, may pass through P E and the valve *g*, and act equally upon the lower as well as the upper surface of the piston; the piston, therefore, being in an unbiassed state, as regards the pressure, will again be raised to its original situation by the counterpoise weights acting at the other end of the beam, and the steam will pass from above to below the piston. When it has arrived at that place, the valves may be again put in their first position, as represented in the drawing, when that at I, being open, affords a communication through O K for the steam, which now occupies the cylinder below the piston, to pass to the condenser, whilst fresh steam forces through D upon the upper surface of the piston tantamount to the pressure of the atmosphere, and produces an effect fully equal to that obtained from an atmospheric engine.

In the engine just described, the beam was drawn down by the pressure of the steam upon the top of the piston, and when the steam had passed into the condenser, was raised by counterpoise weights placed at its further end; by which it is manifest, that the action of an engine of this construction must be somewhat irregular, for whilst the piston is descending, the steam must act upon it to an amount capable of raising the counterpoise weights, and of likewise doing the work put upon it; but when the piston is rising, the actual fall of the counterpoise weights is the only amount of power which the engine is supplying, and from which is to be deducted the friction and weight of the piston. Such engines, therefore, when a continuous and equable force is required, are not so advantageous as those where the rising and depressing of the piston are alike performed by the same means and the same extent of force. This desirable end was accomplished by Mr Watt in the construction of the double-acting engine, which we shall next notice, in contradistinction to the one that last claimed our attention, and which is now seldom used for any other purpose than that of pumping water.

The double-acting engine is formed in such a manner that whilst the steam is pressing on one side of the piston, the cylinder on the other side is always open to the condenser, so that a vacuum exists on the opposite side to that on which the pressure is exerted. This effect is produced by several modes of distributing various pipes, or valves, or cocks. The simplest in its construction is the four-way cock.

Fig. 176. A is the cylinder; B the piston; C the pipe communicating with the boiler; *f m* a communication with the condenser; I K and H *g* communicate to the top and bottom of the cylinder; C¹ and D are two different passages through the plug of a cock, (the plug of the cock is shaded for distinction,) capable of being turned by means of its handle *m* 1. When the cock is as now represented, the steam from C passes through D along H and *g* to beneath the piston, whilst there will be a direct communication with the condenser from above the piston through K I C¹ F M. When the cock is turned in the position as represented in fig. 177, both these communications will be inverted by the different dispositions of their openings. The opening *e* in the plug will then afford a communication from the steam pipe C to I, leading to the upper part of the cylinder; and the opening D will permit a communication from H, leading from the lower part of the cylinder to M, the eduction pipe, leading to the condenser; thus perfecting by its motion the different changes of communication, so that the steam is always made to act on the one side of the piston, whilst the vacuum is effected on the other. The effect on the piston in ascending or descending is equal, and the power is much more regular and convenient for application to rotative motion.

In the single and the double engine the pressure of the atmosphere is not used; but the direct force of the steam which, in the old engines, went to expel the atmosphere, and then by its own condensation to leave a vacuum, is first resorted to, and its condensation leaves a vacuum to assist the action of the next supply. Consequently the single-acting engine has not gained more power than the atmospheric engine in proportion to the steam used, otherwise than by what is saved through keeping the cylinder warm; and the double acting engine is only a mode of using the steam in a more continuous and unbroken manner, taking just twice the quantity of steam, and exerting twice the power of the single-acting engine.

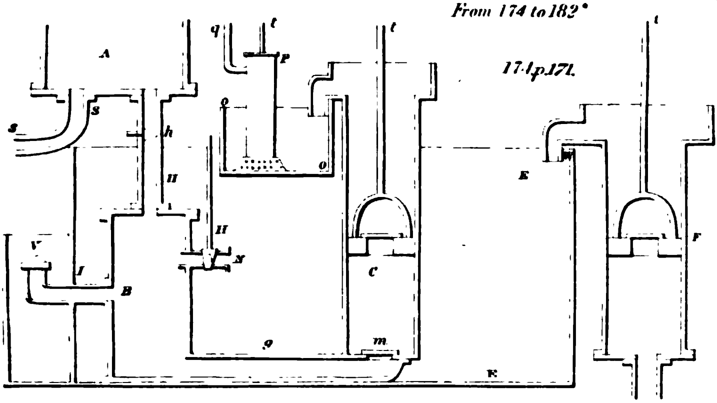
Other modes for attaining this change of communication, so as to produce the double action, are adopted as circumstances may demand. The one last described, called the four-way cock, was found not to answer in large engines, inasmuch as plugs of sufficient dimensions to afford steam-way enough caused so much friction in their collars, that it was an expenditure of considerable power to turn them; the method, therefore, most usually adopted in engines of large

STEAM ENGINE.

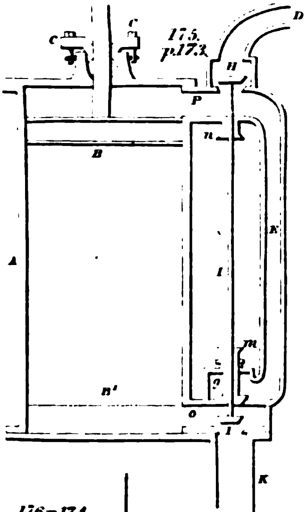
Pl. 20.

From 174 to 182*

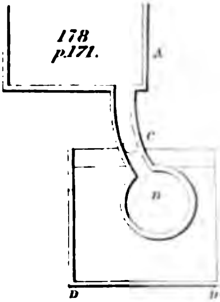
174.p.171.



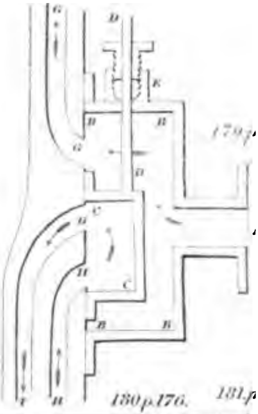
175. p.173.



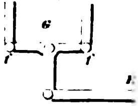
178 p.171.



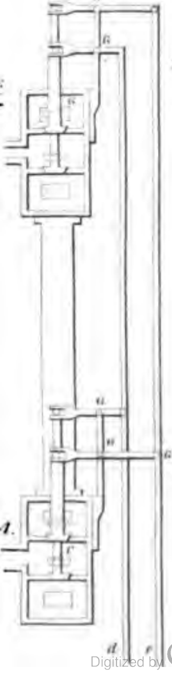
179 p



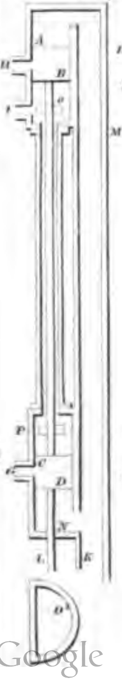
182.*p.178.



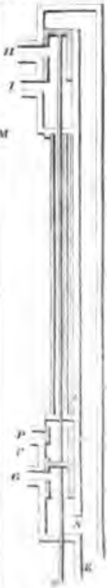
182 p.176



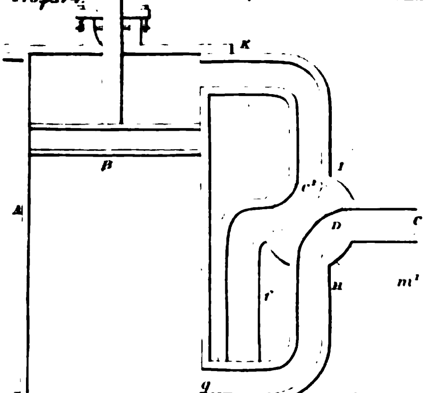
180 p.176.



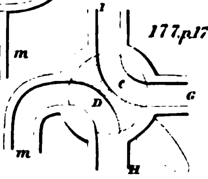
181 p



176.p.174.



177.p.174.



dimensions is, a system of valves, opened and shut at the proper periods by levers.

The internal arrangement of such a system is shown at fig. 173, where C is a pipe leading from the boiler for the conveyance of steam; and D K a pipe leading to L the condenser; *o p*, *m n*, are two boxes, each divided internally into three compartments, in which are the valves *e f g h*, capable of opening upwards. From the centre compartment in each of the boxes above and below there is a communication, at *a* and *b*, with the top and bottom of the cylinder. The steam is conveyed along the pipe C into the upper chamber of the upper box, and by means of the pipe *i* passes through it and proceeds to the upper chamber of the lower box, and the pipe K D affords a communication from each of the lower chambers to the condenser L.

If the valve *h* be opened, there will be a communication from the lower part of the cylinder through the aperture *b* and pipe K into the condenser L; and if, at the same instant, the valve *e* be opened, the steam will be admitted through C into the centre chamber of the upper box, and through the aperture *a* into the upper part of the cylinder; consequently the steam will be admitted to the upper part of the cylinder while the lower part has communication with the condenser, and the piston be forced downwards. If these valves be closed, and the valves *g f* opened, the steam will have access through C *i*, the valve *g*, and aperture *b*, to the lower part of the cylinder, whilst there will be a communication from the top of the cylinder through the aperture *a*, the valve *f*, and the pipe K D, to the condenser, so that the piston will then be forced upwards.

This mode of effecting the changes of communication, though by no means so simple as that of the fore-way cock, has an advantage over it that gives it a decided preference. For as the movements of the valves are independent of each other, the shutting off of the steam, and of the communication with the condenser, can, if desired, be effected at different periods, so that the steam may be allowed to act upon the piston only during one-half of the stroke, which was discovered by Mr Watt to effect a saving in steam. Besides this advantage, which can, if required, be effected in other engines by simple contrivances, the valve geer is superior, from its lightness, when compared to slides or cocks, adapted to large engines.

In small engines, these advantages, not being of so much importance, are more than counterbalanced by the simplicity obtained by other modes.

The first that we shall notice was invented by Mr Murray, of Leeds, and is represented in fig. 179, where a section of this apparatus, termed the slide valve, is shown. A is the steam pipe from the boiler; B B B B a close chamber, in which the interior chamber, C C, is capable of sliding upwards and downwards by means of a rod, D D, which passes through a steam-tight box at E. G G is a passage from the chamber B B B B to the upper part of the cylinder; H H to the lower part of the cylinder; and I I to the condenser. Now when the chamber C C is placed as is represented, it is plain that the steam has access to the top of the cylinder, and that a communication exists by H H and I I to the condenser. By moving C C upwards, the communication would be reversed, that is, G G from the top of the cylinder would communicate by I I to the condenser, and H H admit steam into the lower part of the cylinder. By the movement of C C upwards and downwards, the alternating effect is produced.

Messrs Boulton and Watt introduced another very neat and useful mode of distributing the steam in small engines, denominated D valves, on account of the shape they present when seen in a top view.

Fig. 180. A B and C D represent the two D valves capable of moving upwards and downwards by means of the spindle E. Their faces at A and C are made to fit steam-tight upon the inside of the box, and the back part at B and D, as shown at D 1, is semicircular, to admit of its being packed with hemp, in the same manner as the piston. G and H are communications to the top and bottom of the cylinder; I is the steam way in the boiler, which, in some engines, comes from the jacket of the cylinder; and K is the eduction pipe, which carries the steam to the condenser.

Now if the rod E be moved upwards until the lower surface of A B is above the aperture H, the lower surface of C D will be above the aperture G, consequently the steam from I will pass into the cylinder at H, and the steam from the cylinder will pass through G and N K into the condenser. Again, if the upper surface, A B, be below H, C D will be below G, and the steam will pass through the aperture O, down a pipe behind M K, through P, and, by means of G, will have access to the bottom of the cylinder, whilst a communication will be effected by M K and through H, from the top of the cylinder with the condenser. The rod E passes through steam-tight joints, at top and bottom, into boxes.

Fig. 181 represents another manner of forming valves upon this principle, in which a flat surface is introduced at the back, and the packing is effected by having the faces, backs, and sides of the valves made of brass, and fitted to plates of the same material, which can be screwed against the valves as they wear. The slides or moving parts are shadowed. The position in which they now are will admit the steam to pass from I through H, and the condensation to be effected by passing from G through N to K; but if the slides be moved downwards until the aperture C is opposite G, the upper slide will be below H, and the steam will pass through P into the cylinder by means of G, and exhaustion will take place from H through M to K.

Fig. 182 is a combination of what are called concentric valves. Their distribution is exactly similar to those already explained. The spindles C C of the lower valves, in both the top and bottom boxes, pass through the spindles of the upper valves, which are pipes. This mode of constructing the valves was invented by Mr Murray. They are capable of being moved in many ways; but the one most generally adopted is represented in the figure, where the rods *d e*, attached to the cross-levers that move on the centres G G G G, act upon the valves. Thus the rod *e*, by moving downwards, will raise the solid or the lower spindle valve of the lower box, which opens to the condenser, and the hollow spindle the upper valve of the upper box, which admits steam to the top of the cylinder, while the rod *d* acts upon the other two, and changes the course of the steam and exhaustion, as before shown.

Conceiving that we have sufficiently explained the several modes of guiding the immediate power of steam, we shall in

the next place proceed to examine into the construction of the piston.

A section of the piston most commonly used in condensing engines is exhibited in fig. 183. The lower face of the piston is fixed to the rod *d d*, and the upper face is capable of being raised up upon the rod *d*. Hemp moistened with tallow, called packing, is introduced round the interstice at C E, which, when the upper plate D D is screwed down by the screw at E E, is forced outwards against the sides of the cylinder, so as to render it perfectly steam-tight. As it wears by the friction against the cylinder, more must be forced out by tightening the screws; and when entirely worn, the plate *d d* must be raised and the piston fresh packed.

This construction of the piston answers perfectly for condensing engines; but in high-pressure engines the hemp is destroyed so rapidly by the heat and friction, that pistons formed entirely of metal have been introduced with advantage.

The top view of one kind of metallic piston is represented at fig. 184. A A A A is a ring of brass divided into four equal disconnected portions, resting upon the plate B B, which is affixed to the piston-rod *d d*, as seen in fig. 185; the portions of the ring are forced outwards against the sides of the cylinder by springs of any convenient form pressing from the piston-rod D. A 1, in fig. 185, represents a side view of a similar ring, similarly divided. Its portions are placed upon the ring last described, so that the divisions fall upon the centres of the other four pieces, and are forced against the sides of the cylinder in like manner by springs, and the plate C C is placed over the whole. The upper and the lower sides of the plate and rings are all carefully ground, so as to fit steam-tight. This form of piston, though it has, in some cases, been used for a considerable time with advantage, is, upon the whole, defective, as the rings near the interstices between the segments, must open and allow the steam to gain access to the interior where the springs lie, and from thence, through similar interstices, to the other side of the piston.

A metallic piston of a better construction is shown at fig. 186, consisting of six pieces of brass of the forms represented in the figure, by A B C D E F. A B C are circular, and are made to fit the inside of the cylinder, against which they are forced by the wedge pieces D E F, which have springs behind them. When A B C wear so as to divide at the angles, the wedge pieces protrude themselves against the cylinder, keeping the space always filled. These pistons have, in some cases, been used for many years without requiring alteration.

Having now duly considered the construction of the cylinder, or seat of motion, and the means of distributing the operative power so as to produce a reverting rectilinear action, we shall next proceed to exhibit the manner in which this action is transferred, so as to maintain its continuance.

The movement of a four-way cock may be accomplished by a plug-tree, which is a perpendicular rod attached to the beam of the engine as represented in fig. 187. O P are two studs or pins placed at such a distance from each other, that the upper one, O, shall force the handle N to the situation of N 1, just as the piston shall have reached the lower part of the cylinder, and the pin P is so placed that it shall carry the handle to its original situation at the time when the piston is again to change its direction. But the plug-tree is now seldom used in engines that have a rotative motion; and where there is no rotative motion, the engines are mostly single action, and are applied only to the purpose of pumping, in which the power is only required to be exerted whilst the piston is descending.

In engines for turning mill-work, where a rotatory motion exists, the action is given to the spindle valves, sliding valves, or what ever apparatus is used for the same object, by means of a rod working from the axis of the fly-wheel by an eccentric motion.

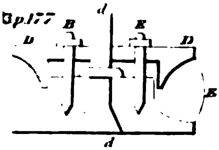
In fig. 188, the small circle is supposed to be a section of the fly-wheel shaft, and B a circular piece on the shaft, round which the clips, or semi-circular pieces, C C, are fastened, so that B can turn on them, therefore when the revolving of the shaft A carries B to the situation of the dotted circle B 1, it is plain that it will have forced the rod in an horizontal direction the distance from the centre of A to B 1, and when in the course of its revolution it shall have brought B to the situation B 2, it will have moved it a similar distance in a contrary direction, consequently the total amount of the horizontal motion thus communicated to the rod D E E will be the amount of the distance from B 1 to B 2. The horizontal is converted into a perpendicular motion by the crank *h g i* raising and lowering the rod K, upon which the slide box or D valves is fixed.

The method for moving the rods of concentric valves is represented in fig. 182*. E is the rod from the eccentric motion, which, by its backward and forward motion, moves the ends *f f* of a T piece, fastened on the centre G, and causes them to move alternately upwards and downwards, opening and shutting each pair of valves as before described.

Fig. 190 represents a mode, applicable to large engines, of moving either D valves or slides from an eccentric. A B is an iron plate, capable of vibrating upon its centre H; F is a rod from the eccentric, moving the weight C upon a roller over the surface of A B. The latch pieces D D 1 move upon two pins, and are prevented falling forwards by the stops M N. The rod of the valves, shown at *e*, is attached by the lever P H to the shaft from the centre H. The two stops, I and G, support A B in the two positions shown, the one in the view, the other by the dotted lines. When the rod F moves, it carries C towards A by the eccentric motion, and C, acting on the same, raises the latch D, and permits the end A of A B to fall, whilst the end B, in rising, latches itself at D 1, shown in the dotted representation of A B. By this motion H P, on the same axis H, is moved downwards, carrying with it the rod E attached to the slides; and the motion of C, instantly changing towards F, acts upon the other latch D 1, and places the slides in their former position.

As the beam of all engines vibrates upon a centre, of course it performs portions of a circle with each of its extremities; and as the rod of the piston is required to move up and down in a straight line, it cannot be attached to the end of the beam. In single engines of the old construction, where the action was a pull at both ends of the beam, (at the one end by the weight of the pump-rod, and at the other by the down stroke of the piston,) a chain was fixed to the upper

3 p.177



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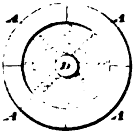

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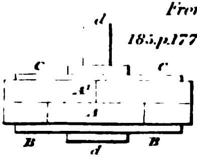

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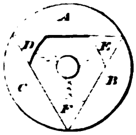

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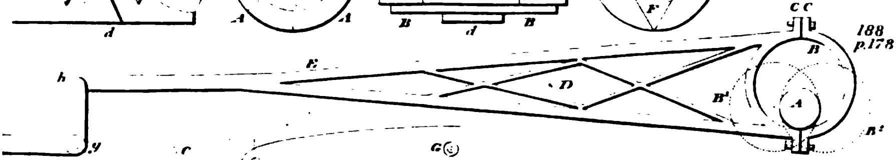

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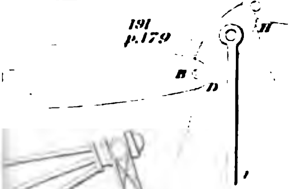

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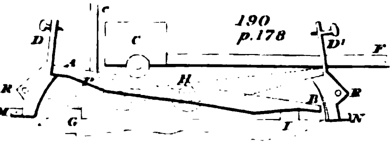

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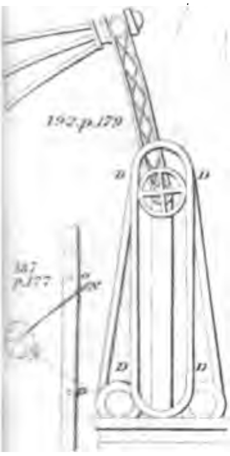
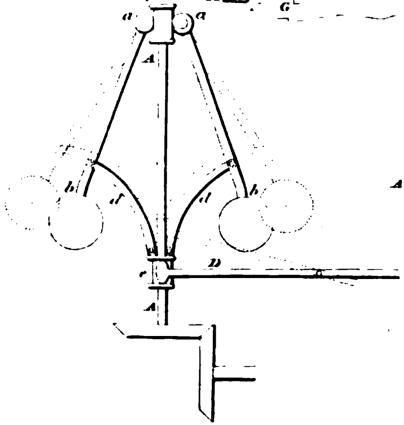


189 p.36



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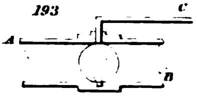

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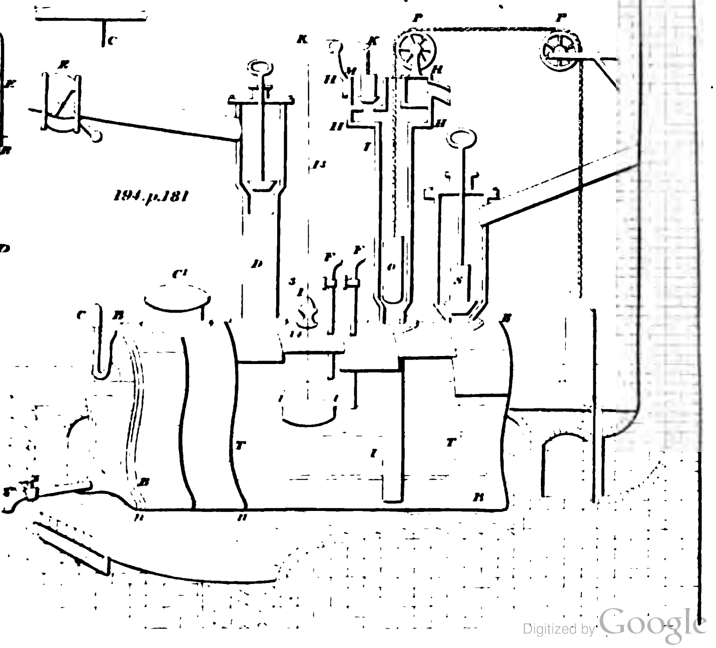
194. p.181



part of each of the curved ends of the beam, and to the pump and piston rods, as represented in fig. 170, which answered the required purpose; but in double-acting engines, where the piston-rod forces upwards as well as pulls, some other mode of converting the action is required. The most perfect yet introduced is the parallel motion, the principle of which may be comprehended by referring to fig. 191.

Suppose A B to represent one end of a beam, vibrating on its centre at A, the other end B will perform the arc C C1, and carry whatever is attached to it in the direction of that arc; then suppose another rod, G H, of equal length to A B, vibrating on its centre G, the point in the connecting piece, L H, will, by the vibrations of A B and H G, move upwards and downwards in a perpendicular line. For so much as the curve from the radius A B draws it towards A, so much will the curve of the radius H G draw it towards G, and the movements, correcting each other, will cause I to rise and fall in a perpendicular line.

A more simple mode, which answers very well in small engines, is represented in fig. 192. The sling piece attached to the end of the beam has a pair of rollers, one on each side, which press on each side of the guiding bars D D D D, and carry the piston, attached at C, in a perpendicular line.

All steam engines are proportioned to go at a settled rate, and to make a certain number of strokes of the piston per minute, which, reckoning the number of feet the piston travels in its upward and downward motion in the cylinder, has been by general agreement settled at 200 to 220 feet per minute.

To obtain this regularity of action, it is manifest that a regularity must be obtained in the amount of power that is to produce the movement; or, in other words, a regular amount of elastic force must be exerted at each stroke of the piston. This is somewhat difficult to accomplish, and depends much upon keeping the fire, which generates the steam, of a uniform heat; consequently the care of the fire should only be intrusted to one who is well skilled in his business. There are, however, contrivances, called governors, which greatly assist in maintaining a regular action, and where very great nicety is not required, they produce it to a sufficient extent.

The governor, (which we have already described under the article "*On the Equalization of Motion*," in Mill-geering,) acts upon the principal of centrifugal force, and is applicable only to engines that have a rotative motion.

The mode of applying the governor is by connecting it by means of levers to a throttle valve, shown in fig. 193. A B represents a section of the pipe that conveys the steam from the boiler, having a small circular fan of iron, capable of being turned so as to be parallel with the line of the pipe, or of lying across it in such a manner as to stop the communication.

The governor is placed at any convenient part of the engine, upon an upright spindle, and is driven either by a band or by bevil-wheels, from the fly-wheel shaft. When the fly-wheel increases or decreases in velocity it transmits the same to the governor, and causes the balls to fly from, or approach nearer to, each other; and the lever affixed to the collar of the governor turns the handle C of the throttle valve, which regulates the supply of steam, and produces regular motion.

In single-acting engines, which do not create rotative motion, this sort of governor cannot be applied, nor is it decidedly adapted to the sort of regulation they want; for as they act only one way, and the steam being entirely shut off at the end of every stroke, it is a regulation of the amount of power to be exerted at every interval which is sought, rather than a continuous equable supply of steam.

This sort is most wanted in engines that supply towns with water, as when the different districts are being supplied, the diversity of their magnitude and situation causes a considerable variation in the burden thrown upon the engine. In engines used for this purpose there are two pieces of wood, called spring-beams, placed across each end of the beam, which, when the burden is lightened, and the engine makes too long a stroke, strike, as they descend, the upper floor of the engine-house and ring a bell, to warn the attendant that steam must be shut off earlier, or that the upper tapit of the plug-tree must be moved downwards. In engines of recent construction, the spring-beams are made to strike a lever, which either shuts off the steam entirely, or opens a cock that admits it into the cylinder: in either case the movement of the engine ceases.

The regulation of the plug-tree tapit is obtained by introducing a pipe from the water in the air-vessel to a small cylinder, having a working piston. The water from the air-vessel forces against the under side of the piston and raises it and its rod, and by that motion the tapit of the plug-tree is raised or lowered as is required. This mode, from error in construction, or otherwise, has mostly proved inefficient when the burden of the engine is liable to great and rapid fluctuations.

Such is the general construction of engines now in use: but there are many ingenious contrivances in boilers which require special notice.

Fig. 194 represents a boiler fitted up with all the appendages now generally applied and set in a furnace of a proper construction. Part of the furnace is shown in a sectional view. B B B B the boiler, the operation of which has been described. C, the steam-gauge, represented at large in fig. 195. Its object is to ascertain the pressure acting in the boiler. It is formed of a bent iron tube, at one end A communicating with the boiler, and at the other end B open to the atmosphere. The tube is filled up to C and D with mercury, and has a thin piece of stick, E, placed in the leg B, which floats perpendicularly in the mercury at D. To the leg B is appended a flat piece of brass, divided into inches, and numbered upwards, to form a scale. The stick is made of such length that the top of it shall be even with the first mark on the scale.

If the steam in the boiler presses against the mercury at C, and raises the surface, D, one inch, (which will be indicated by the end of the stick rising to 1 upon the scale,) it proves that there is one half pound pressing per square inch against the internal surface of the boiler, tending to burst it; for if the section of the bore of the pipe was just one superficial inch, the pressure would be supporting one cubic inch, of mercury, which will be found to weigh near half a pound; therefore for every two inches rise, one pound pressure may be reckoned, and as condensing engines seldom work with more than three or four pounds pressure upon the inch, the scale need not be longer than eight or nine inches.

C 1 is a strong iron plate, covering a circular or oval hole of about 18 inches diameter, to admit a man into the boiler with a view to clean or examine it.

D is the steam pipe, containing the throttle valve E, to which the rod from the governor is connected. F F are gauge cocks. I I is a feed pipe which passes into the boiler and reaches very near to the bottom. H H H H the cistern, on the top of the feed pipe; *i i* is a float, formed of stone, and balanced so as to remain always on the surface of the water in the boiler. By the raising and falling of the water the float acts upon the lever K K 1 by the wire I 3, which passes through a steam-tight joint at I 4, and as the water sinks, draws down the end K which raises K 1, and the valve M attached to it. By this contrivance when the boiler requires a fresh supply of water the valve M opens and supplies it from the cistern H H H H.

The feed pipe I I is made to contain a column of water equal to the amount of pressure exerted by the steam in the boiler, which we have already stated should not exceed the supporting of eight inches of mercury. As one inch of mercury being equal in weight to about 13½ inches of water, the pipe should be about nine feet high from the surface of the water when the boiler is supplied; and the water in the feed pipe should stand about three feet when the pressure is six inches of mercury, or three pounds to the square inch of surface.

The feed pipe contains likewise an iron bucket weight O, hung by a chain that passes over two pullies, P P; to the other end of the chain is attached a sheet of iron called a damper. When the steam in the boiler is urged to too great an extent, it forces the water in the feed pipe upwards, and raises the iron bucket weight O, which lowers the damper into the flue of the chimney, and checks the force of the fire.

S is a safety valve, loaded with a determinate weight, and of such a dimension in the bore, as will relieve the boiler of its pressure should it arrive beyond a certain temperature. It is enclosed in a case, to prevent the engine tender having access to it, as some engine tenders have been known to load the safety valves, to save themselves the trouble of attending to the fire with that diligence which is necessary, and by which they have endangered their own lives as well as the lives of others.

A pipe proceeds from this case to the chimney, to carry whatever steam may escape into the flue of the chimney.

There is very frequently another safety valve, which is open to the view of the engine tender, to indicate when the fire is too high.

T T is a flue formed of sheet iron, and passing lengthwise through the centre of the boiler so near the bottom that it is always covered with water.

The flame and smoke from the fire at *n n* passes first under the boiler, and then immediately returns back through this flue, then dividing itself, passes through flues which lead it on both sides the boiler to the chimney.

V is a cock for the purpose of emptying the boiler when required to be cleaned or repaired.

Such is the construction and general arrangement of the parts of Messrs Boulton and Watt's engines, both single and reciprocating. We shall now proceed in the examination of some other forms of engines which likewise condense their steam.

Mr Hornblower, conceiving he could obtain greater power from the communicated force of steam acting in two cylinders, obtained a patent, in 1781, for that object. His own account, taken from the specification, we here transcribe.

"First," says Mr H. "I use two vessels, in which the steam is to act, and which in other engines are called cylinders. Secondly, I employ the steam after it has acted in the first vessel to operate a second time in the other, by permitting it to expand itself, which I do by connecting the vessels together, and forming proper channels and apertures, whereby the steam shall occasionally go in and out of the said vessels. Thirdly, I condense the steam, by causing it to pass in contact with metalline surfaces, while water is applied to the opposite side. Fourthly, to discharge the engine of the water used to condense the steam, I suspend a column of water in a tube or vessel constructed for that purpose, on the principles of the barometer, the upper end having open communication with the steam vessels, and the lower end being immersed in a vessel of water. Fifthly, to discharge the air which enters the steam vessels with the condensing water or otherwise, I introduce it into a separate vessel, whence it is protruded by the admission of steam. Sixthly, that the condensed vapour shall not remain in the steam vessel in which the steam is condensed, I collect it into another vessel, which has open communication with the steam vessels and the water in the mine, reservoir, or river.

"Lastly, in cases where the atmosphere is to be employed to act on the piston, I use a piston, so constructed as to admit steam round its periphery, and in contact with the sides of the steam vessel, thereby to prevent the external air from passing in between the piston and the sides of the steam vessel."

The following is a description of this engine by the inventor: "Let A and B, fig. 196, represent two cylinders, of which A is the largest; a piston moves in each, having their rods, C and D, moving through collars at E and F. These cylinders may be supplied with steam from the boiler by means of a square pipe G, which has a flanch to connect it with the rest of the steam pipe. This square part is represented as branching off to both cylinders: *c* and *d* are two cocks, which have handles and tumblers as usual, worked by the plug-beam W. On the fore side of the cylinders, (that is, the side next the eye,) is represented another communicating pipe, whose section is also square, or rectangular, having also two cocks, *a*, *b*. The pipe Y, immediately under the cock *b*, establishes a communication between the upper and lower parts of the small cylinder B, by opening the cock *b*. There is a similar pipe on the other side of the cylinder A, immediately under the cock *d*.

"When the cocks *c* and *a* are open, and the cocks *b* and *d* are shut, the steam from the boiler has free admission into the upper part of the small cylinder B; and the steam from the lower part of B has free admission into the upper part of the great cylinder A; but the upper part of each cylinder has no communication with its lower part.

"From the bottom of the great cylinder proceeds the eduction pipe K, having a valve at its opening into the cylinder; it then bends downward, and is connected with the conical condenser L. The condenser is fixed on a hollow box M, on which stand the pumps N and O, for extracting the air and water, which last runs along the trough T into a cistern U, from which it is raised by the pump V, for recruiting the boiler, being already nearly boiling hot. Immediately under the condenser there is a spigot valve at S, over which is a small jet pipe, reaching to the bend of the eduction pipe K. The whole of the condensing apparatus is contained in a cistern, R, of cold water; a small pipe, P, comes from the side of the condenser, and terminates on the bottom of the trough T, and is there covered with a valve, Q, which is kept tight by the water that is always running over it.

"Lastly, the pump-rods, H, cause the outer end of the beam to preponderate, so that the quiescent position of the beam is that represented in the figure, the pistons being at the top of the cylinders.

"Suppose all the cocks open, and steam coming in copiously from the boiler, and no condensation going on in L, the steam must drive out all the air, and at last follow it through the valve Q. Now shut the cocks *b* and *d*, and open the valve S of the condenser; the condensation will immediately commence, and draw off the steam from the lower part of the great cylinder. There is now no pressure on the under side of the piston of the great cylinder A, and it immediately descends. The communication, Y, between the lower part of the small cylinder, B, and the upper part of the great cylinder, A, being open, the steam will go from the lower part of B into the space left by the descent of the piston of A. It must, therefore, expand, and its elasticity must diminish, and will no longer balance the pressure of the steam coming from the boiler, and pressing above the piston of B.

"This piston, therefore, if not withheld by the beam, would descend till it came in equilibrio, from having steam of equal density above and below it. But it cannot descend so fast; for the cylinder A is larger than B, and the arch of the beam, at which the great piston is suspended, is no longer than the arm which supports the piston of B; therefore, when the piston of B has descended as far as the beam will permit it, the steam between the two pistons occupies a larger space than it did when both pistons were at the top of their cylinders, and its density diminishes as its bulk increases. The steam beneath the small piston is, therefore, not a balance for the steam on the upper side of the same, and the piston B will act to depress the beam with all the difference of these pressures.

"The slightest view of the subject must show the reader, that as the pistons descend, the steam that is between them will grow continually rarer and less elastic, and that both pistons will draw the beam downwards. Suppose now, that each one had reached the bottom of its cylinder, shut the cock *a*, and the eduction valve at the bottom of A, and open the cocks *b* and *d*. The communication being now established between the upper and lower part of each cylinder, their pistons will be pressed equally on the upper and lower surfaces; in this situation nothing, therefore, hinders the counterweight from raising the pistons to the top.

"Suppose them arrived at the top: the cylinder B is at this time filled with steam of the ordinary density, and the cylinder A with an equal absolute quantity of steam, but expanded into a larger space. Shut the cocks *b* and *d*, and open the cock *a*, and the eduction valve at the bottom of A, the condensation will again operate, and cause the pistons to descend; and thus the operation may be repeated as long as steam is supplied; and once full of the cylinder B of ordinary steam, is expended during each working stroke."

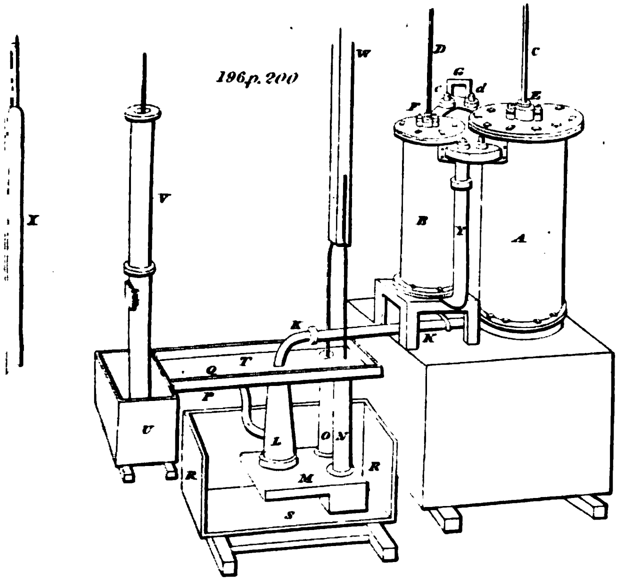
The cocks of this engine are composed of two flat circular plates, ground very true to each other, and one of them turns round on a pin through their centres: each is pierced with three sectorial apertures, exactly corresponding with each other, and occupying a little less than one-half of their surfaces. By turning the movable plate so that the apertures coincide, a large passage is opened for the steam; and by turning it so that the solid part of the one covers the aperture of the other, the cock is shut. Such regulators are now very common in the cast-iron stoves for warming rooms. Mr Hornblower's contrivance for making the collars for the piston rods air-tight is thus: the collar is in fact two, placed at a small distance from each other, and a small pipe, branching off from the steam pipe, communicates with the space between the collars. This steam, being a little stronger than the pressure of the atmosphere, effectually prevents the air from penetrating through the upper collar; and though a little steam should get through the lower collar into the cylinder A, it can do no harm. The manner of making this stuffing-

STEAM ENGINE.

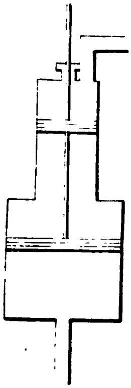
From 196 to 200.

Pl. 22.

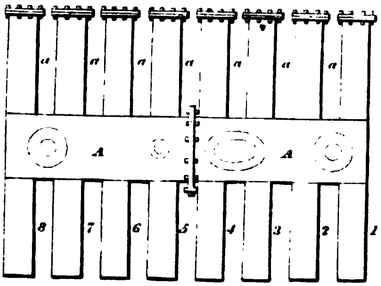
196.p.200



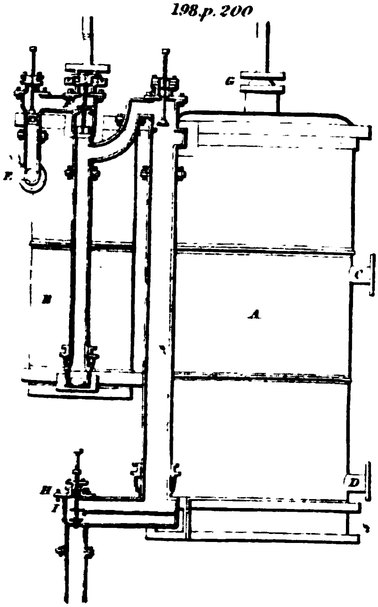
197.p.185



199.p.202



198.p.200



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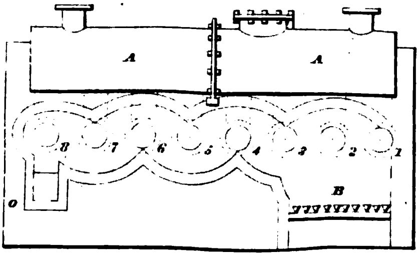


box is as follows: on the top of the cylinder is a box to contain something soft, yet pretty close, to embrace the piston-rod in its motion up and down; and this is usually a sort of plaited rope of white yarn, nicely laid in, and rammed down gently, occupying about a third of its depth; upon that is placed a sort of tripod, having a flat ring of brass for its upper, and another for its lower part; and these rings are in breadth equal to the space between the piston-rod and the side of the box. This compound ring being put on over the end of the piston-rod, another quantity of this rope is to be put upon it, and gently rammed as before; then there is a hollow space left between these two packings, and that space is to be supplied with strong steam from the boiler. Thus is the packing about the piston-rod kept in such a state as to prevent the air from entering the cylinder when at any time there may be a partial vacuum above the piston.

Mr Hornblower's description of this engine was followed by a mathematical investigation of the principles of its action, by the ingenious Professor Robison, which demonstrates that it is the same thing in effect as Mr Watt's expansion engine; but though this is true, there is a considerable difference in the steps by which the effect is attained, which gives an important advantage when it is reduced to practice. We shall give an investigation in a more popular form, using only common arithmetic. Mr Hornblower assumed, that the power or pressure of steam is inversely as the space into which the steam is expanded; this is the case with air, and for the present we will grant it to be so with steam, and reaſon from the same data as the ingenious inventor gives us.

To explain clearly what passes in the two cylinders, we must deviate from the precise form of the engine, and divest ourselves of one complication of ideas, by reducing both cylinders to the same stroke; therefore, suppose the engine to be made like fig. 197, which represents the two cylinders placed one upon the other, the lower one being double the capacity of the upper one, and both pistons being attached to the same rod, which may be applied to the end of the beam, so that the descent of the pistons must draw up the load at the opposite end of the beam.

Then, if we suppose the small piston to be ten inches in diameter, the great piston must be 14,14 inches; and to avoid all difficulties of the ratio of the expansion, and the pressure of steam, we will suppose the engine to be worked by the pressure of atmospheric air instead of steam; and for the convenience of round numbers in our calculation we will consider the pressure at only ten pounds per circular inch on the surface of the piston.

The area of the small piston will be 100 circular inches, and being assumed to move without friction, the pressure upon it will be 10 × 100 = 1000 pounds. The area of the great piston is twice as much, or 200 circular inches, and the pressure 2000 pounds.

Suppose both pistons to be at the top of their respective cylinders; let the atmospheric air be admitted to press freely upon the upper surface of the small piston; and suppose the space between the two pistons filled with air of the same density, while there is a perfect vacuum made in the lower part of the great cylinder, beneath its piston.

Under these circumstances, the two pistons will begin to descend with something less than 2000 pounds of pressure on the great piston, by the air contained in the space between the two pistons bearing on the 200 inches of surface with a weight of 10 pounds per inch; and beneath this piston there is nothing to counteract the pressure. At the same time, the small piston, having air of equal density above and below it, is in equilibrio.

This force would balance a load of 2000 pounds; but suppose we diminish the load to 1900 pounds, then the pistons will immediately begin to descend; but they will soon stop, because the air between the two pistons must expand itself, to fill the increasing space occasioned by the equal descent of both pistons in the cylinders, one of which is twice the area of the other; and as the air becomes rarer, its pressure on the great piston must diminish. Now as this same diminution occasions the small piston to have a power of descent, we will first consider the pistons separately, and then conjointly, in their power of descent, with which they draw down the beam.

Descending power of the great piston.	*lbs.*	*Descending power of the small piston.*	*lbs.*	*Combined powers of both pistons.*	*lbs.*
At first the power will be In consequence of the pressure of 10 pounds per circular inch upon its upper surface, and no pressure beneath.	2000	At first the power will be Because the piston is in equilibrio, having 1000 pounds pressing upwards, and 1000 pounds downwards.	0	At first - - -	2000
At one-fourth of the descent, the power will have diminished, by regular decrements, to Because the air between the two pistons must occupy three-fourths of the small cylinder, and one-fourth of the great cylinder, which is a space equal to one and one-fourth of the original space which it filled; therefore the spaces will be as 5 to 4; and if the density of air is as the inverse proportion of the space which it occupies, the pressure on the great piston must be as 4 to 5, or four-fifths of 2000 = 1600.	1600	At one-fourth, the power will be - - - - - Because the equilibrium does not continue, and at one-fourth of the descent the pressure beneath the small piston is reduced by the expansion of the air between the two pistons to four-fifths of 1000 = 800 pounds, while the pressure above the piston continues to be 1000. The power is, therefore, 1000 — 800 = 200.	200	At one-fourth	1800
At one-half of the descent, the power will have diminished to Because at this position the air between the pistons occupies one-half of the small cylinder and one-half of the great one, which is a space equal to one and one-half of the space it filled originally. The spaces will therefore be as 6 to 4, and the pressure on the great piston as 4 to 6, or two-thirds of 2000 = 1333 1-3.	$1333\frac{1}{3}$	At one-half of the descent the power will have increased to - Because the pressure beneath is diminished by the increased rarity of the air to two-thirds of 1000=662 2-3, while the downward pressure continues to be 1000. The power is therefore 1000 — 662 2-3 = 333 1-3.	$333\frac{1}{3}$	At one-half -	$1666\frac{2}{3}$
At three-fourths of the descent, the power will be only Because the air must now occupy one-fourth of the small cylinder, and three-fourths of the large cylinder, which is a space equal to one and three-fourths of the original space. Thus the spaces will be as 7 to 4, and the pressure on the great piston four-sevenths of 2000 = 1142 6-7.	$1142\frac{6}{7}$	At three-fourths of the descent, the power will be - - - - - - Because the pressure beneath is reduced by the rarity of the air to four-sevenths of 1000 = 571 3-7; therefore the power is 1000 — 571 3-7 = 428 4-7.	$428\frac{4}{7}$	At three-fourths	$1571\frac{3}{7}$
At the bottom of the cylinder the power will be Because the air must occupy the whole of the large cylinder, a space equal to twice the small cylinder which it at first filled. The pressure will therefore be one-half of 2000.	1000	At the bottom, the power will be - - - - - Because the air beneath the piston is reduced to one-half of its pressure, or 500, which, deducted from 1000, leaves 500	500	At the bottom	1500
Sum of the powers exerted by the great piston in its descent.	7076	Sum of the powers of the small piston -	1461	Sum of the combined powers.	8538

Upon the action of this engine Dr Rees, in his Cyclopædia, presents us with the following remarks and comparative statement between it and Mr. Watt's principle of expansion.

Now let us consider how Mr Watt's principle of expansion would operate in the same circumstance; that is, in a cylinder of 14,14 inches diameter; which is to be supplied with air of 10 pounds pressure per circular inch, until it has completed one-half of its descent, and leaving the remainder of the descent to be accomplished by the expansion of the air already contained in the upper half of the cylinder.

	lbs.
At the beginning, the power of descent will be	2000
At one-fourth, the power will still be	2000
At one-half, the power will be	2000
At three-fourths of the descent, the power will be diminished to	1333⅓
Because the air must occupy one-fourth of the length of the cylinder, in addition to that half of the cylinder which it occupied before the expansion began; therefore the space is one and a half times the former, or as 3 to 2, and the pressure will be two-thirds of 2000.	
At the bottom the pressure will be	1000
Because the air is expanded to occupy twice the space it filled before.	
	8333⅓

The sum total is very nearly the same as the former, but both are greater than they should be, from the imperfect manner in which we have been obliged to make our calculation, so as to express it in common arithmetic without having recourse to fluxions, which is the only method of treating quantities that are constantly increasing or decreasing by any given law.

The source of the inaccuracy is easily explained: at first we set with the pressure at 2000 pounds in Mr Hornblower's engine, and did not take into the account that it decreases at all, until the piston has descended to one-fourth, but reasoned as though it diminished all at once at that place; whereas it began to diminish from the very first starting. Here then we have taken a small quantity too much. In the same manner, our process takes no notice of the diminution which happens between one-fourth and one-half of the descent, or between the other points at which we have chosen to examine it; the result is, as if the diminution took place suddenly at each of those points. The remedy for this would have been to have taken the account at a greater number of places, as it is by fluxions alone that we can take an infinite number, so as to obtain a true result. Now in the second calculation of Mr Watt's expansion-engine, we have taken a still less number of steps for the consideration of the expansion, because, although there are four steps in the process, two of them are before the expansion begins.

This is the reason of the apparent difference; for in reality there is none in the sum total of the varying powers exerted through the whole stroke, as will appear to any person who will take the trouble to read Professor Robison's investigation. But if we consider the difference of the manner in which the whole power is expended during the stroke, we shall see great reason to prefer Mr Hornblower's method, from the much greater uniformity of the action; it begins at 2000, and ends at 1500, whilst Mr Watt's begins at 2000, and ends at 1000; hence the necessity of those ingenious contrivances for equalizing the action in Mr Watt's patent of 1782. Mr Hornblower's is not uniform, but approaches uniformity more nearly, so that he could have carried the effect of the expansive principle much farther, in employing stronger steam, than we believe he ever proposed to do.

We have been thus full upon this subject, because the gaining more power by the expansion of air or steam acting in double cylinders, has been a favourite idea with many, and there are no less than five different patents for it, but several of these have been upon mistaken notions; neither Mr Watt's nor Mr Hornblower's can have any advantage from shutting off the air, or from a double cylinder, when air is used to press the piston; nor could they derive any advantage from the expansion of steam in their engines, if the pressure of it was inversely as the space it occupies.

The advantage of the expansive principle arises wholly from a peculiar property of steam, by which, when suffered to expand itself to fill a greater space, it decreases in pressure or elastic force by a certain law, which is not fully laid down; that is, the relation between its expansive force and the space which it occupies is not clearly decided: but Mr Woolf has found that, by applying these properties in their fullest extent to the double-cylinder engine, he can make most important improvements in the effects which can be obtained from any given quantity of fuel. Steam is a fluid so different from air, as to have no one property in common with it, except elasticity. This elasticity is wholly derived from the quantity of heat which it contains, and its force increases and diminishes with the quantity of heat; but by what law it increases or diminishes we are uncertain, because we have no measure of the actual quantity of heat which is contained in steam of any given elastic force. All we know with certainty is what is stated in our table of expansion, viz. that water, being converted into steam, and confined in a close vessel, when heated until the thermometer indicates a certain temperature, will have a certain pressure or elastic force. But here we must observe, that the thermometer indicates only the intensity of the heat, without affording a direct measure of its quantity. When steam is suffered to expand itself into any given space, the quantity of rarefied water which will be found to be contained in any given bulk of steam, in its expanded state, must be undoubtedly proportioned to the quantity of water contained in the same bulk of the steam, before the expansion took place, in the inverse ratio of the space which it originally occupied, and that space which it fills when expanded; but we cannot say that this is the case with heat; and it is the quantity of heat alone which determines the elastic force.

We believe that, in practice, Mr Hornblower was not able to obtain any greater effect from the application of the expansive action in two cylinders, than Mr Watt did in one cylinder. In 1791—2, he erected an engine in Cornwall at Tin-Croft mine, of which the large cylinder was 27 inches diameter, and worked with a stroke of eight feet long, and the small cylinder 21 inches diameter, working with a six feet stroke. The only account we have been able to obtain of the performance of this engine, is from a pamphlet published by Thomas Wilson, an agent of Messrs Boulton and Watt, professedly with a view to prevent the introduction of Mr Hornblower's engines into that country, in which he makes it appear, that it raised only 14,222,120 pounds of water one foot high with each bushel of coals.

In Mr Hornblower's own account of his engine, in Gregory's *Mechanics*, he informs us, "That an engine was erected in the vicinity of Bath, some years since, on this principle, and under very disadvantageous circumstances, the engine had its cylinders 19 inches and 24 inches diameter, with lengths of stroke in each suitable to the occasion: viz. six feet and eight feet respectively. The condensing apparatus was very bad, through a fear of infringement on Mr Watt's patent, and the greatest degree of vacuum which could be obtained, was no more than 27 inches of mercury. The engine worked four lifts of pumps to the depth of 576 feet, 4500 pounds, 14 strokes in a minute, six feet each, with a cylinder six feet long, and 19 inches diameter, with a great deal of inertia and friction in the rods and buckets;

some of the latter of which were not more than 3¼ inches diameter: and this it did, under all these disadvantageous circumstances, with 70 pounds of coal, (light coal,) per hour."

To reduce this to the standard of one foot high, we must put the load 4500 pounds × 6 feet stroke = 27,000 pounds which the engine raised one foot high at every stroke; 27,000 pounds × 14 strokes per minute = 378,000 pounds raised one foot high each minute; 378,000 pounds × 60 = 22,680,000 pounds raised one foot high per hour, or with 70 pounds of coals. As the coals are stated to be light, we will take them at only 84 pounds per bushel, instead of 88 pounds, as Mr Smeaton did, and say as 70 pounds : 22,680,800 pounds : : 84 pounds : 27,216,000 pounds of water raised one foot high with a bushel of coals, which is a very good performance, but not greater than Mr Watt's.

In this engine, Mr Hornblower says that two remarkable circumstances presented themselves to show the advantages of this application of the principle: the one was, that the man who attended the engine would sometimes detach the smaller cylinder from the beam, and work only with the large one, and then the boiler would scarcely raise steam enough to keep the engine going; but no sooner was the small cylinder-rod attached to the beam, than the engine resumed its wonted activity, and the steam would blow up the safety-valve.

The next circumstance is, that when the detent, which kept the exhausting valve shut, happened to miss its action, the piston would be checked, as it were, not being permitted to rise through the whole of the returning stroke; and it would, as by an intuitive nature, come down again and again, until the detent performed its office, which is a practical argument for the power of the engine at the termination of its stroke.

Several engines have been constructed upon the principles of admitting a further expansion of the steam in a second cylinder. The one, however, which has been most effectually tried by comparison, is that which goes by the name of Woolf's engine. An account of which we transcribe, together with other improvements in the minor parts, which from their ingenuity are worthy of notice.

In 1804, Mr Arthur Woolf had a patent for improvements in steam-engines. The specification of his invention states, that he has ascertained by actual experiment, and reduced to practice, the following particulars respecting the expansibility of steam. That, in practice, it is found that steam, acting with the expansive force of four pounds pressure per square inch against a safety-valve exposed to the atmosphere, is capable of expanding itself to four times the volume it then occupies, and still to be equal to the pressure of the atmosphere: that, in like manner, steam of the force of five pounds the square inch, can expand itself to five times its volume; and that masses or quantities of steam of the like expansive force of six, seven, eight, nine, or ten pounds pressure per square inch, can expand to six, seven, eight, nine, or ten times their volume, and still be respectively equal to the atmosphere, or capable of producing a sufficient action against the piston of a steam-engine, to cause the same to rise in the atmospheric engine of Newcomen with a counterpoise, or to be carried into the vacuous part of the cylinder of the improved engine, first brought into effect by Mr Watt: that this ratio is progressive, and nearly, if not entirely, uniform; so that steam pressing with the expansive force of 20, 30, 40, or 50 pounds the square inch against a common safety-valve, will expand itself to 20, 30, 40, or 50 times its volume; and that, generally, as to all the intermediate or higher degrees of elastic force, the number of times which steam of any temperature and force can expand itself, is nearly the same as the number of pounds it is able to sustain on a square inch exposed to the common atmospheric counter-pressure; provided always, that the space, place, or vessel, in which it is allowed to expand itself, be kept at the same temperature as that of the steam, before it is allowed room to expand.

Respecting the different degrees of temperature required to bring steam to, and maintain it at, different expansive forces above the weight of the atmosphere, Mr Woolf states, that he has found by actual experiment, setting out from the boiling point of water, or 212° of Fahrenheit, at which degree steam of water is only equal to the pressure of the atmosphere; that, in order to give an increased elastic force equal to five pounds on each square inch, the temperature must be raised to about 227½°, when it will have acquired a power to expand itself to five times its volume, and still be equal to the atmosphere, and capable of being applied as such in the working of steam-engines according to his invention. Various other pressures, temperatures, and expansive forces of steam, are shown in the following table.

Woolf's Table of the relative pressures per square inch; the temperature and expansibility of steam at different degrees of heat above the boiling point of water, beginning with the temperature of steam of an elastic force equal to five pounds per square inch, and extending to steam able to sustain forty pounds on the square inch.

	Pounds per Square Inch.		Degrees of Heat.			
Steam of an elastic force predominating over the pressure of the atmosphere upon a safety-valve	5	requires to be maintained by a temperature equal to about	227½	and at these respective degrees of heat, steam can expand itself to about	5	times its volume, and continue equal in elasticity to the pressure of the atmosphere.
	6		230¼		6	
	7		232¾		7	
	8		235¼		8	
	9		237½		9	
	10		239½		10	
	15		250½		15	
	20		259½		20	
	25		267		25	
	30		273		30	
	35		278		35	
	40		282		40	

And so in like manner, by small additions of temperature, an expansive power may be given to steam to enable it to expand to 50, 60, 70, 80, 90, 100, 200, 300, or more times its volume, without any limitation but what is imposed by the frangible nature of every material of which boilers and other parts of steam-engines can be made. Prudence dictates that the expansive force should never be carried to the utmost which the materials can bear, but rather be kept considerably within that limit.

Having thus explained the nature of his discovery, Mr Woolf proceeds to give a description of his improvements grounded thereon.

If the engine is constructed originally with the intention of adopting these improvements, it ought to have two steam cylinders of different dimensions, and proportioned to each other, according to the temperature or the expansive force determined to be communicated to the steam made use of in working the engine; for the smaller steam-vessel or cylinder must be a guide for the larger. For example; if steam of forty pounds the square inch is fixed on, then the smaller cylinder should be at least one-fortieth part the contents of the larger one. Each cylinder should be furnished with a piston, and the smaller cylinder should have a communication, both at its top and bottom, (top and bottom being here employed merely as relative terms, for the cylinders may be worked in a horizontal, or any other required position, as well as vertical,) with the boiler which supplies the steam; and the communications, by means of cocks or valves of any construction adapted to the use, are to be alternately opened and shut during the working of the engine. The top of the small cylinder should have a communication with the bottom of the larger cylinder, and the bottom of the smaller one with the top of the larger, with proper means to open and shut them alternately by cocks, valves, or any other well-known contrivance. And both the top and bottom of the larger cylinder should, while the engine is at work, communicate alternately with a condensing vessel, into which a jet of water is admitted to hasten the condensation; or the condensing vessel may be cooled by any other means calculated to produce that effect.

This arrangement being made, when the engine is set to work, steam of a high temperature is admitted from the boiler to act by its elastic force on one side of the smaller piston, while the steam which had last moved it has a communication with the larger steam-vessel or cylinder, where it follows the larger piston, now moving towards that end of its cylinder which is open to the condensing vessel. Let both pistons end their stroke at one time; and let us now suppose them both at the top of their respective cylinders, ready to descend; then the steam of forty pounds the square inch, entering above the smaller piston, will carry it downwards; while the steam below it, instead of being allowed to escape into the atmosphere, or applied to any other purpose, will pass into the larger cylinder above its piston, which will make its downward stroke at the same time that the piston of the smaller cylinder is doing the same thing; and while this goes on, the steam which last filled the larger cylinder in the upward stroke of the engine will be passing into the condenser, to be condensed during the downward stroke. When the pistons in the smaller and larger cylinder have thus been made to descend to the bottom of their respective cylinders, then the steam from the boiler is to be shut off from the top, and admitted to the bottom of the smaller cylinder. The communication between the bottom of the smaller and the top of the larger cylinder is also to be cut off; and the communication is to be opened between the top of the smaller and the bottom of the larger cylinder. The communication between the bottom of the larger cylinder and the condenser is to be cut off, and the steam which, in the downward stroke of the engine, filled the upper part of the larger cylinder, suffered to flow off to the condenser. The engine will then make its upward stroke from the pressure of the steam in the top of the small cylinder acting beneath the piston of the great cylinder, and so on alternately, admitting the steam to the different sides of a smaller piston, while the steam last admitted into the smaller cylinder passes alternately to the different sides of the larger piston in the larger cylinders: the top and bottom of which are at the same time made to communicate alternately with the condenser.

In an engine working in the manner just described, while the steam is admitted on one side of the piston into the smaller cylinder, the steam on the other side has room made for its admission into the larger cylinder, on one side of its piston, by the condensation taking place on the other side of the large piston which is open to the condenser; and that waste of steam which takes place in engines worked only by the expansive force of steam, from steam passing the piston, is prevented; for all steam that passes the piston in the smaller cylinder is received into the larger.

In such an engine, where it may be more convenient for any particular purpose, the arrangement may be altered, and the top of the smaller made to communicate with the top of the larger cylinder; in which case the only difference will be, that when the piston in the smaller cylinder descends, that in the larger will ascend, and *vice versâ;* which, on some occasions, may be more convenient than to have the two pistons moving in the same direction.

This engine is exactly the same in its action as Mr Hornblower's, which we have before described. The novelty consists in the application of steam of a high pressure thereto, and in proportioning the capacities of the two cylinders to the expansibility of the steam, according to his table. But Mr W. goes on to state, that effectual means must be used to keep up the requisite temperature in all parts of the apparatus into which the steam is admitted, and in which it is not intended to be condensed; and here it may be proper to state, that instead of the usual means of accomplishing this, by enclosing them in the boiler, or in a steam-case communicating with the boiler, a separate fire may with advantage be made under the steam-case containing the cylinders, which in that event will become a second boiler, and must be furnished with a safety-valve, to regulate the temperature. By means of the last-mentioned arrangement, the steam from the smaller cylinder, or steam measurer, may be admitted into the larger cylinder, when kept at a higher temperature than the steam in the smaller cylinder, by which its power to expand itself may be increased; and, on the contrary, by keeping the larger cylinder at a lower temperature than the smaller, its expansibility will be lessened, which, on particular occasions, and for particular purposes, may be desirable. In every case care must be taken that the boiler, or case in which the cylinder is enclosed, the steam-pipes, and generally all the parts exposed to the action of the expansive force of the steam, shall have a strength proportioned to the high pressure to which they are to be exposed.

It is not advisable that the proportion of the capacity of the smaller cylinder, or steam-measurer, to the capacity of the larger or working cylinder, should in any case be smaller than the proportion of the expansion of the steam which is to be used in it, as we have stated, yet, in the making of it larger, considerable latitude may be allowed; for example, with steam of forty pounds the square inch, a small cylinder, or measurer, of one-twentieth, or even larger, instead of one-fortieth the capacity of the larger or working cylinder, and so with steam of any given strength. And in many cases it may be advisable that this should be the case, because of the difficulty of preventing some waste of steam, or partial condensation, which might lessen the rate of working, if not allowed for in the size of the small cylinder or steam-measurer.

In all cases when the engine is ready for working, whatever may be the proportion that has been adopted, or intended to be worked with, it should have its power tried by altering the load on the valve that ascertains the force of the steam, in order that the strength of steam best adapted for the engine may be ascertained, for it may turn out to be advantageous, that the steam should be employed in particular engines of an elastic force somewhat over or under what was first intended.

Mr Woolf also states, that Mr Watt's engines may be improved by the application of his discovery in making the boiler, and the steam-case in which the working cylinder is enclosed, much stronger than usual, and by altering the structure and dimensions of the valves for admitting steam from the boiler into the cylinder in such a manner that the steam may be admitted very gradually by a progressive enlargement of the aperture, so as at first to withdraw the steam and afterwards to admit it more freely. The reason of this precaution is this, that steam of such elastic force as Mr Woolf proposes to employ, if admitted suddenly into the cylinder, would strike the piston with a force as would endanger the safety and durability of the engine. The aperture allowed for admitting steam into the cylinder, or cylinders, should be regulated by the following consideration. If the intention is that the engine should work wholly, or almost wholly, by condensation, the steam, in passing into the cylinder, should be forced to withdraw itself only so much that the piston may perform the whole, or a great part of the stroke, by the time that the intended quantity of steam has been admitted into the cylinder. For example, when steam of forty pounds on the square inch is used, such a quantity of it must be allowed to enter as shall be equal to one-fortieth of the capacity of the cylinder, and so in proportion when steam of any other force is employed; and when the requisite quantity has been admitted, the steam is to be shut off till the proper moment for admitting a fresh quantity. But if it is intended that advantage shall also be taken of the elastic force of the steam acting on one side of the piston, while condensation goes on on the other side, then the steam must be admitted more freely, but still with caution at first, for the reason already mentioned.

This latter is the same thing as Mr Watt's expansion engine; but with the addition of gradually diminishing the aperture of the steam-valve as the piston descends, instead of stopping it altogether at a certain portion of the descent, by which means the action of the engine is rendered more uniform. We think that, by regulating the descent of the valve by an accurate movement, a very good effect may be produced in this manner, without the complication of two cylinders or other parts; the only objection is, that if at any time the valve should be fully opened by accident, the pressure might suddenly become so great, from the strong steam acting upon the full surface of the piston, as to break the engine to pieces.

In 1805, Mr Woolf took out a second patent for further improvements, in which he proposes, as before, to apply fire to the cylinder itself, to heat the steam after it is thrown into the working cylinder; and this was to be done by a fire being placed beneath the case containing the cylinder: the space between the case and the cylinder was to be filled with oil, wax, fusible metal, or mercury. He also proposes a method of preventing the passage of any of the steam from that side of the piston which is acted upon by the steam, to the other side, which is open to the condenser. In those steam-engines which act as double engines, he effects this by employing, upon or about the piston, a column of mercury or fluid metal, in an altitude equal to the pressure of the steam. The efficacy of this arrangement will, he says, appear obvious, from attending to what takes place in the working such a piston. When the piston is ascending, that is, when the steam is admitted below it, the space on its upper side being open to the condenser, the steam, endeavouring to pass up by the side of the piston, is met, and effectually prevented by the column of metal, equal or superior to it in pressure, and during the down stroke, no steam can possibly pass without first forcing all the metal through.

In working what is called a single engine, a less considerable altitude of metal is required, because the steam always acts on the upper side of the piston; and in this case, oil, or wax, or fat of animals, or similar substances, in sufficient quantities, will answer the purpose. But care must be taken, either in the double or single engine, when working with this piston, that the outlet which conveys the steam to the condenser shall be so situated, and of such a size, that the steam may pass freely, without forcing before it, or carrying with it, any of the metal or other substance employed that may have passed by the piston; and at the same time providing another exit for the metal, or other substance collected at the bottom of the cylinder, to convey the same into a reservoir kept at a proper heat, whence it is to be returned to the upper side of the piston by a small pump, worked by the engine, or by some other contrivance. In order that the fluid metal used with the piston may not be oxydated, some oil or other fluid substance is always to be kept on its surface, to prevent its coming in contact with the steam; and to prevent the necessity of employing a large quantity of fluid metal, although the piston must be as thick as the depth of the column required, the diameter need be only a little less than the steam-vessel or working cylinder, excepting where the packing, or other fitting, is necessary to be applied; so that, in fact, the column of fluid metal forms only a thin body round the piston.

We have seen an engine of an eight-horse power of this kind at work, with a fluid metal on the pistons: it effectually prevented the leakage. But as it required to have the cylinders twice as long as usual, in order to have sufficient room for the long or thick pistons which it required, and as these pistons must be of considerable weight, the method is not at all applicable in practice; and, indeed, the increase of the bulk of the moving parts is such as to counterbalance the advantage, which is confined to the saving of steam by leakage; for the friction must be greater than in another engine, because the piston must be packed as tight as usual, to be able to sustain a column of fluid metal, which must be more than equal in pressure to that of the steam; and when the steam presses upon the piston, the pressure of the fluid metal to leak by the piston must be double that of the steam: also the friction of so great a surface of fluid metal pressing against the inside of the cylinder is very great.

In 1810, Mr Woolf had a third patent, the object of which is to prevent the waste of steam from leakage by the piston. For this purpose he does not allow the steam to come to the piston at all, but causes it to act in a different vessel, and transmits the action thereof to the piston by oil or fluid metal: thus, at the side of the cylinder, he places a separate vessel, communicating with the lower part of the cylinder by a large pipe or passage from the bottom of each; then steam, being admitted into this vessel, will press upon the surface of the oil or fluid metal contained in it, and force the same to pass out of that vessel into the cylinder, where it will act beneath the piston to press the same upwards, a vacuum being at the same time made in the upper part of the cylinder to give effect to the pressure.

The steam is then made to press upon the upper surface of the piston, which is always covered with a quantity of the fluid; and at the same time a vacuum is made in the separate vessel, so as to relieve the surface thereof from all pressure; in consequence the piston is made to descend. It is evident that the piston must be packed so tight as to suffer none of the fluid to pass by it; but this is easy, in comparison with the difficulty of making a packing sufficiently tight to resist the passage of steam, particularly when it is so rare as the expanded steam which Mr Woolf sometimes uses in his engine. The separate vessel of which we have spoken, is in some cases to be the jacket or space which surrounds the cylinder, which is then to be open at bottom.

This contrivance is ingenious, but we think the necessity of an additional cylinder is an objection which will prevent its adoption in large engines; and for small engines the advantages are not so great.

Since his first patent, Mr Woolf has erected several small engines, which performed well, and with an evident economy of fuel. But these engines being employed to turn mills, of which the operations do not afford so exact an estimate of the power as the operation of pumping water, Mr Woolf's engines did not come to a direct and indisputable comparison with those on Mr Watt's principle, until 1815, when two large engines were set to work in Cornwell, at Wheal Vor and Wheal Abraham mines, for pumping water; and these have since been regularly reported in Messrs T. and J. Lean's reports, and of which one of the objects was to ascertain the comparative merit of the double and single cylinder engines.

The report for May 1815, states the average performance of these two engines at 49,980,882 lbs. lifted one foot high for each bushel of coals; and since that time they have done more than 50,000,000 lbs.

The engine at Wheal Vor has a great cylinder of 53 inches diameter, and nine-feet stroke; and the small cylinder is about one-fifth of the contents of the great one. The engine works six pumps, which, at every stroke, raise a load of water of 37,982 lbs. weight 7½ feet high, which is the length of the stroke in the pumps. This makes a pressure of 14,1 lbs. per square inch on the surface of the great piston, and it makes 7,6 strokes per minute. With respect to its consumption of coals, it raised, in March 1816, 48,432,702 lbs. one foot high with each bushel; April 1816, 44,000,000 lbs.; May 1816, 49,500,000 lbs.; and in June 1816, 43,000,000 lbs.

From the same reports we learn, that the engine at Wheal Abraham mine has a great cylinder of 45 inches diameter, working with a seven-feet stroke, at the rate of 8,4 strokes per minute under a load of 24,050 lbs. which it raises seven feet at each stroke. Its performance during the above four months was 50,000,000 lbs.; 50,908,000 lbs.; in May, 56,917,312 lbs. which, we believe, is the greatest performance ever made by a steam-engine; and in June, 51,500,000 lbs.

We must observe, that the variation in the performance of different steam-engines, which are constructed upon the same principle, and working under the same advantages, is the same as would be found in the produce of the labour of so many different horses, or other animals, when compared with their consumptive food; for the effects of different steam-engines will vary as much from small differences in the proportions of their parts, as the strength of animals from the vigour of their consitution; and, again, there will be as great differences in the performance of the same engine, when in bad or good order, from all the parts being tight and well oiled, so as to move with little friction, as there is in the labour of an animal, from his being in good or bad health, or excessively fatigued; but in all cases, there will be a maximum which cannot be exceeded, and an average which we ought always expect to attain.

Fig. 198 is a sketch to show the arrangement of the valves and cylinders of these two engines; A is the large cylinder, and B the little cylinder, each enclosed in its steam-case. The steam is admitted from the boiler into the steam case of the large cylinder A, by a communication at C; and there is a communication between this steam-case and that of the small cylinder; so that all the steam for the supply of the engine passes through both of the steam-cases, which therefore become part of the communication between the boiler and the little cylinder, into which the steam is first admitted. D furnishes a communication for carrying back to the boiler any water which may be produced by condensation in the steam-case, before the engine is heated to the proper temperature. E is the pipe from the steam-case to supply the engine; it has a regulating valve. F is the valve-box of the small cylinder, the spindle of the one valve working through that of the other; and the passage for the steam from the case into the small cylinder is situated between the two valves. G is the valve that opens the communication between the bottom of the small cylinder B and the top of the large cylinder A, when the piston thereof is to be pressed down. H is the valve that returns the steam from above to below the large piston, when the piston is to ascend. And I is the exhaustion-valve, to carry off the steam to the condenser.

When the engine makes its down-stroke, the upper valve at F is opened, and admits the steam from the case to press upon the small piston, the valve G being opened at the same time, which suffers the steam to pass from the under side of the small to the upper side of the large piston; and the valve I is opened to make a passage from beneath the great piston to the condenser. These three upper valves, F, G, I, open at the same instant of time.

When both pistons arrive at the bottom of their respective cylinders, these three valves are shut altogether, and the lower steam-valve at F is opened, to return the steam from above to below the small piston, the valve H doing the same to the large cylinder, and both pistons return in equilibrio by the counter-weight; but the upper valve at F can be shut off at any part of the stroke, according to the load of the engine.

Those who are conversant with steam-engines will perceive, from the passing of the steam, as above described, from the upper to the lower side of each of the pistons respectively, that the engines at Wheal Vor, and at Wheal Abraham, are at present working with a single stroke. Were these engines working double, the steam would, on the down-stroke, be made to pass, the same as before described, from the under side of the small to the upper side of the large piston, steam from the boiler in the mean time coming in upon the small piston, and the under side of the large piston being open to the condenser; but on the up-stroke, the action would be different from what we have described, for the steam would pass from the top of the small cylinder to beneath the large piston, while steam would be admitted from the boiler under the small piston, the top of the large cylinder being open to the condenser.

The boilers which Mr Woolf employs in his engines are different from those of other engines which work with steam of a low pressure, the water being contained in small cylindrical tubes of cast-iron, which are filled with water, and exposed to the flame nearly in an horizontal position.

Mr Woolf has a patent for this boiler, which the specification states to consist of two or more cylindrical vessels, properly connected together, and so disposed, as to constitute a strong and fit receptacle for the water intended to be converted into steam of a temperature and under a pressure uncommonly high, and also to present an extensive portion of convex surface to the current of flame and heated air from a fire; likewise of other large cylindrical receptacles placed above the former cylinders, and properly connected with them, for the purpose of containing some water and the steam.

These cylindrical vessels are set in a furnace so adapted to them, as to cause the greater part of the surface of each of them, or as much of the surface as may be convenient, to receive the direct action of the fire, or heated air or flame.

Figs. 199 and 200 represent one of these boilers in its most simple form. It consists of eight tubes marked *a*, made of cast-iron, or any other fit metal, which are each connected with the larger cylinder A, placed above them, as is shown in the side view, fig. 200, in which the same letters refer to the same parts as in fig. 199. In fig. 200 is also shown the manner in which the fire is made to act. The fuel rests on the grate-bars at B, and the flame and heated air, being reverberated from the part above the two first smaller cylinders, go under the third, over the fourth, under the fifth, over the sixth, under the seventh, and partly over and partly under the eighth small cylindric tube, all which tubes are full of water. The direction of the flame, until it reaches the last-mentioned tube, is shown by the dotted curved lines and arrows. When it has reached that end of the furnace, it is carried by the flue, O, to the other side of a wall, built beneath the main cylinder A, in the direction of its length, and the flame then returns under the opposite end of the seventh smaller cylinder over the sixth, under the fifth, over the fourth, under the third, over the second, and partly over and partly under the first, when it passes into the chimney. The wall before-mentioned, which divides the furnace longitudinally, answers the double purpose of lengthening the course which the flame and heated air have to traverse, giving off heat to the boiler in the passage, and also of securing the flanges, or other joinings, employed to unite the smaller tubes to the main cylinder, from being injured by the fire. The ends of the small cylindric tubes rest on the brickwork which forms the sides of the furnace, and one end of each of them is furnished with a cover, secured in its place by screws and a flanch, but which can be taken off at pleasure, to allow the tubes to be cleared, from time to time, from any incrustation or sediment which may be deposited in them.

To any convenient part of the main cylinder A, a tube is affixed, to convey the steam to the steam-engine. In working with such boilers, the water carried off by evaporation is replaced by water forced in by the usual means for a high pressure boiler, that is, a forcing-pump; and the steam generated is carried to the place intended by means of pipes connected with the upper part of the cylinder A. In the specification, means are pointed out for applying this plan to the boilers of steam-engines already in use, by ranging a row of cylinders beneath the present boiler, and connecting them with each other, and with the boiler. Directions are also given for constructing boilers composed of cylinders disposed vertically. In every case the tubes composing the boiler should be so combined and arranged, and the furnace so constructed, as to make the fire and flame act around and over the tubes, so as to embrace the largest possible quantity of their surface. It must be obvious to any one, that the tubes may be made of any kind of metal; but cast-iron is the most convenient. The size of the tubes may be varied; but in every case, care should be taken not to make the diameter too great; for it must be remembered, that the larger the diameter of any single tube is in such a boiler, the stronger it must be made in proportion, to enable it to bear the same expansive force of steam as the smaller cylinders. It is not essential, however, to the invention, that the tubes should be of different sizes; but the upper cylinders, especially the one which is called the steam cylinder, should be larger than the lower ones, it being the reservoir, as it were, into which the lower ones send the steam, to be thence conveyed away by the steam-pipe. The following general directions are given respecting the quantity of water to be kept in a boiler of this construction, viz. it ought always to fill, not only the whole of the lower tubes, but also the great steam cylinder A, to about half its diameter, that is, as high as the fire is allowed to reach; and in no case should it be allowed to get so low, as not to keep the vertical necks, or branches, which join the smaller cylinders to the great cylinder, full of water, for the fire is only beneficially employed when applied, through the medium of the interposed metal, to water, to convert it into steam; that is, the purpose of the boiler would in some measure be defeated if any of the parts of the tubes which are exposed to the direct action of the fire, should present a surface of steam in their interior, instead of water, to receive the transmitted heat. This must, more or less, be the case, whenever the lower tubes, and even a part of the upper, are not kept filled with the water.

Respecting the furnace for this kind of boiler, it should always be so built as to give a long and waving course to the flame and heated air, forcing them the more effectually to strike against the sides of the tubes which compose the boiler, and so to give out the greatest possible portion of their heat before they reach the chimney. Unless this be attended to, there will be a much greater waste of fuel than necessary, and the heat communicated to the contents of the boiler will be less from a given quantity of fuel.

When very high temperatures are not to be employed, the kind of boiler just described is found to answer very well; but where the utmost force of the fire is desirable for producing the most elastic steam, the parts are combined in a manner somewhat different, though the principle is the same. In the *Philosophical Magazine*, vol. xvii. p. 40, is a description and drawing of a boiler of this kind, two of which were erected, in 1803, at Messrs. Meux's brewery.

In every case Mr Woolf uses two safety-valves, at least, in his apparatus, to prevent accidents; a precaution which cannot be too strongly enforced, as it may happen, when but one is employed, that by some accident it may get locked, and the engine and people about it be exposed to the danger of an explosion.

In those engines of Mr Woolf's which we have seen, he employs boilers like the one described, viz. with two small tubes beneath, which are full of water, and exposed to the immediate action of the flame, communicating by perpendicular necks or branches with the large cylinder above, which has water in the lower part, and steam in the upper. The only difference from what we have above described is, that the lower and upper tubes are placed in the same direction, instead of being at right angles to each other; and the flame proceeds in the direction of their length, instead of crossing them; the lower or water tubes are rather inclined upwards. The metal of these tubes is made very thick, with a view to strength and durability.

The idea of making boilers for raising strong steam by a number of small tubes, which can be made stronger than one large vessel, is not original with Mr Woolf, Mr Blakey, of whom we have before spoken, having proposed it in a small tract which he published in French, at the Hague, in 1776. But his tubes were to be placed over each other, in an inclined direction, and the water, being admitted at the upper end, ran down within the heated inclined tubes, and became converted into steam.

Woolf's regulating steam valve.—Besides the common safety-valves, Mr Woolf has also introduced a valve of a new construction into the steam-pipe itself, to regulate the quantity that shall pass from the boiler. In fact, it is a self-acting steam-regulator, and extremely ingenious.

A, (fig. 201,) is a part of the great or steam cylinder of one of Mr Woolf's boilers; B B, the neck or outlet for the steam, surmounted by a steam-box C, which is joined to the neck B B, by the flanges, *a*, *a*. The top or cover of the steam-box C, marked with the letter D, is well secured in its place, and has a hole through it for the rod of the valve to pass: and the interior of the hole is formed to a box to hold a stuffing, and make the rod work up and down steam tight, the stuffing being kept in its place by means of a collar, screwed down in the usual way, as shown in the figure. By means of a pin *b*, and the two vertical pieces *e*, *e*, the sliding-valve rod is made fast to *m*, which is a close cover to the hollow cylinder *n n*. The cover *m* fits steam-tight into the conical seat, at the upper end of a collar *o o*, which is made fast to the flange *a a*, and descends into the neck of the boiler, forming a barrel, in which the cylinder fits close. The cylinder *n n* is open at bottom, having a free communication with the steam in the boiler A; and it has three vertical slits cut through the slides, one of which, S, is shown in the plate. The sum of the area of all these slits or openings is equal to the area of the opening of the seat or collar *o o*, in which the cylinder *n n* works.

When the steam acquires a sufficient degree of elastic force to raise the valve, (that is, the cylinder *n n*, with its cover *m*, and the rod R,) together with whatever weight the rod may be loaded, then the openings S, rising above the steam-tight collar or seat *o o*, allow the steam to pass into the steam-box C, and to flow off to the engine through the pipe N. But the quantity of steam that passes is proportioned to the elastic force it has acquired, and the weight with which the valve is loaded; because the rise of the openings, S, above the collar *o o*, will be in that proportion.

This valve may be loaded by applying weights in any of the usual methods; but Mr Woolf prefers the one shown in the drawing, in which the upper part of the rod R is joined, by means of a chain, to a quadrant of a circle Q, for the purpose of carrying a pendulum weight Z, that admits of being moved nearer to or farther from the centre of the quadrant, according as the pressure of the valve is wished to be increased or diminished.

As the valve rises, the weight moves upwards in the arc *n n*, giving a continually increased resistance to the farther rising of the valve, proportioned to the horizontal distance of the weight from the centre of Q, of which the weight attains a continual increase by its rise in the area, according to the horizontal distances measured on the line Q *p*, pressing through the centre of the weight by perpendiculars from the horizontal line.

Thus, if the weight Z presses down the valve *m* with a force equal to 20 pounds on the square inch of the aperture in *o o*, in its present position, when it rises to the position at *i*, it will press with a force equal to 30 pounds, and at *p*, with a force equal to 40 pounds on the square inch; so that the rod Z may be made to serve at the same time as an index to the person who attends the fire, nothing more being necessary for this purpose than to graduate the arc, described by the end of the rod Q Z, by experimental trials. In the side of the steam-box C there is an opening, N, to allow the steam to pass from it by a pipe to the steam-engine.

It is plain that the adjustment of the positive pressure on this valve can be determined by sliding the weight Z of the pendulum to a greater or less distance from the centre of motion. Again, to adjust the rate of the increasing forces, so as to correspond with the increasing force of the steam, the radius of the quadrant, Q, must be apportioned to the diameter of the valve and the opening of the slits, S, so that the ascent of the weight Z, in its quadrant will be correspondent to the varying pressure. This adjustment must be made as nearly as it can be done before the valve is fixed; and to bring it afterwards to an exact regulation, the chain is attached to the rod, R, by a nut and screw; by means of which, any part of the arc can be used that is found most correspondent with the varying pressure, because the rate at which the resistance of the lever increases is more rapid when the pendulum is near to the perpendicular, than when it approaches the horizontal position.

The same effect may be produced, by making the slits in the side of the cylinder narrower at the lower part of the cylinder, instead of being parallel.

BELL-CRANK ENGINE.

Messrs Boulton and Watt, soon after the expiration of their patent for effecting condensation in a separate vessel, introduced a form of engine, called the bell-crank engine, of which we shall represent so much as is necessary to exhibit the alteration in the mode of construction.

Fig. 202 is a side view of the engine. A B C is the bell-crank, there being another exactly similar part on the other side, moving upon a fixed centre, C; the end A D is joined to a cross-piece which works the piston-rod in the cylinder. E serves for the air-pump, and G for the cold-water pump, and the hot-water pump may be worked upon the same bar. The connecting rod from B to H is supposed to be attached to the crank of the fly-wheel at H. Engines of this description are mostly constructed with slide or D valves, which are worked by the beam A C. This form of engine does not possess any particular advantages otherwise than those arising from compactness, which are not of sufficient weight to counterbalance the increased friction. It was, in some few instances, at the commencement of steam navigation, applied to boats, but it was found to answer not so well as the double-beam engine.

VIBRATING ENGINE.

With a view to do away with the beam of the engine, and to communicate the motion direct from the piston-rod to the fly-wheel crank, a form of engine has been constructed, which, in engines of small dimensions, where the piston-rod can be made of sufficient strength compared with the weight of the cylinder that is to vibrate, have answered tolerably well. We have seen one of about one-horse power, which had been at work four years.

Fig. 203. A is the cylinder, B the piston-rod, C the crank, D the fly-wheel E a stand supporting the cylinder pivot F, which has a similar one on the opposite side. One of these pivots is formed like the key of a four-way cock, having a communication to the top and bottom of the cylinder. By the movement of the piston, the cylinder is caused to vibrate, to turn the crank and fly-wheel, and the steam passes alternately to the top and bottom of the cylinder, by the two-way axes on which the cylinder vibrates.

When engines of this construction are formed of any considerable size, there is a danger of bending the piston-rod, and in vibrating, the weight of the cylinder loosens its fitting in the stuffing collar of the cylinder-cap.

ROTATORY ENGINE.

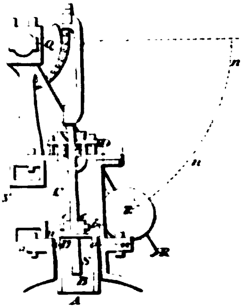
All steam-engines as yet noticed, have their action produced by the movement of a piston in a cylinder and act by what is called a reciprocating motion. In engines of this description, a very considerable degree of power is expended in arresting the motion of the different working parts, and putting them into action in a direct contrary course : this has claimed much attention from engineers, and many attempts have been made to construct an engine in which the action of the steam should operate in a continuous manner, without bringing the parts to a state of rest.

The most obvious mode of attaining this object, is the producing a rotatory motion. One of the most simple engines on this construction is represented in fig. 204, where two sections are shown, the one at right angles to the revolving shaft, the other parallel to it, the same letters in both denoting the same parts. U U U U is a circular steam-case, with the

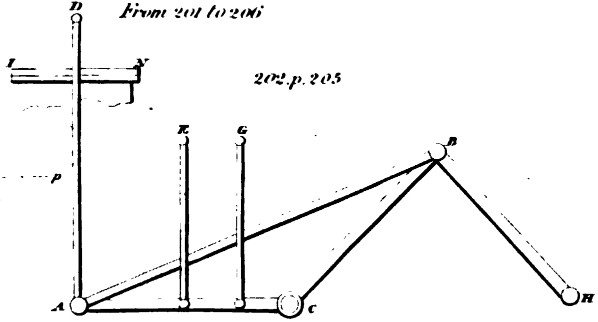
STEAM ENGINE.

From 201 to 206

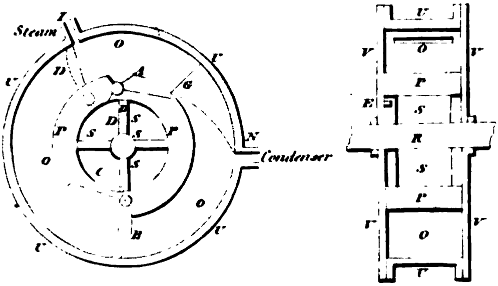
201. p. 204



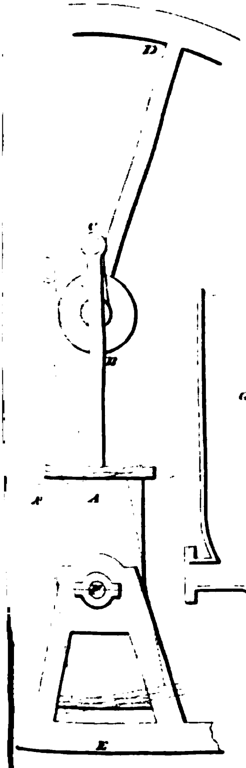
202. p. 205



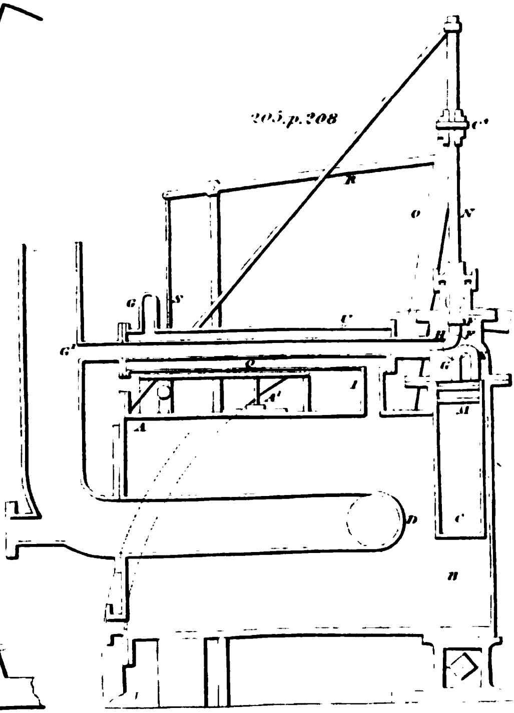
204. p. 207



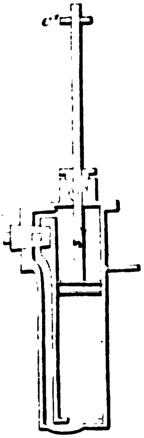
203. p. 206



205. p. 208



206. p. 208



two ends enclosed by the circular plates V V V V, through which the shaft R passes. To R is attached by four arms, S S S S, the ring P P, in which the fans or flat pieces, A and B, are fixed on hinges formed steam-tight, but capable of being shut in upon the ring, as A, or opening and closing the steam-course O O O O, as B. To each of these four pieces is attached a tail or tripping piece, C and D, which, during their revolution, touch the stud E, and raises their respective fans into the steam-way, as shown by the dotted fan at A 1, just after it has passed the steam aperture, I. The passage to the condenser is represented at N; G is a camb-piece attached to the outer case, and fitting in a steam-tight manner upon P P P P, serving to close the fans as they come round. The steam entering at I presses upon G and A 1, which is supposed to have been just raised to that position, and forces it round together with the ring P P P P, and the centre shaft R, until it passes the aperture through which the steam issues to the condenser, prior to which the other fan, B, passes the steam-way, and obtains a position to receive the action of the steam, and continue the motion.

The steam-way, O O O O, may be considered to be a cylinder bent round, and the fans, as they obtrude themselves, act the part of a piston, receiving the impulse of the steam always on the one side, and effecting the condensation always on the other. It being requisite that the steam-way should have some termination, the obstacle, G, is indispensable, and the movement of the fans upon hinges, or some other mode, to pass such obstacle, is unavoidable; and therefore, from being thus compelled to move the piece acting as a piston continually to and from its fittings, it becomes extremely difficult to maintain those fittings steam-tight. This, together with the steam-way not being capable of receiving the cylindrical form, are inconveniences of great moment. It has been found, therefore, that in maintaining engines of this construction in a working condition, great difficulties arise, which hitherto have not been surmounted; and as at present these engines exist to no useful end, we shall refrain from describing them further.

HIGH-PRESSURE ENGINES.

If water be urged greatly by fire, steam of greater pressure is obtained; and it has been long known, that the extent of the pressure increases in a greater ratio than the expenditure of heat, which has been an inducement to many to attempt to use steam at excessive pressures. The pressures generally allowed in high-pressure engines, is not more than 30, 40, and seldom exceeds 50 pounds to the inch.

In engines where the pressure is so great, the weight of the atmosphere is not taken into account, and the mode of effecting the motion of the piston is, by allowing one end of the cylinder to be open to the air, whilst the steam acts on the opposite side of the piston. By this mode of operation, all the parts appertaining to the promotion of condensation, are dispensed with, and, consequently, the expense of making those parts, the friction caused by their operations, and the attention which was necessary to their well-being, is entirely saved. This gives to the engine a peculiar degree of simplicity, but it is unfortunately attended with some danger.

Steam was applied in this mode so early as the year 1724, and is described by Leupold, in his *Theatrum Machinarum Hydraulicarum*, vol. ii. p. 93. The engine thus described, is formed with two cylinders, having pistons fitted and attached to two separate beams, whose other ends are connected with two force-pumps. Between the two cylinders is a four-way cock, and as the pistons are weighed and brought down to the bottom of each cylinder, it is evident that by means of this cock, the steam can be let on alternately to the bottom of each cylinder, whilst, at the same time, the opposite cylinder to that in which the steam is admitted has a communication with the atmosphere. Thus by turning the cocks, the two pistons are alternately raised by the steam, and permitted to descend by the loading of weights attached to their other end. This simple construction of high-pressure may be placed on a par with Newcomen's condensing engine.

Mr Watt presents to our notice this mode of using the direct action of steam, in the latter part of his specification, in 1769; but the most common application of high-pressure steam, of late years, is used in a form of engine invented by Mr Trevitheck, for the purpose of applying this power to locomotion. He obtained a patent for it, in union with Mr Vivian, in the year 1802. This engine, from its compactness, is peculiarly applicable to this purpose, as it requires no condensing water, which would be an insurmountable bar to its introduction.

Fig. 205 presents a section of this form of engine. A B is the boiler, A1 a safety-valve, C D the cylinder, E the four-way cock, G the passage from the boiler, H the passage to the chimney, G1 for the exit of the steam. E is a four-way cock, F the passage to the top, and K the passage to the bottom of the cylinder. M the piston, N the piston-rod, O the connecting rod, joined to the cranks of the fly-wheel. The beam R is worked by the connecting rod, which has the rod of a small force-pump S attached to it, acting on the other side of the boiler, and forcing water along Q U into the boiler by I. The fire-place is behind the chimney, as seen in the view, and is surrounded on all sides by the boiler. Fig. 206 is a section of the cylinder at right angles to the section at fig. 205. The four-way cock is moved by means of a lever on its axis, which is struck by a tapit upon a rod from the cross-piece C². It must be understood that there is another connecting rod and crank on the farther side of the engine, and that the beam C² connects them.

This engine, we conceive, requires little elucidation. The four-way cock permits the steam to pass alternately to the top and bottom of the cylinder by the passages F and K, and affords it egress by G¹: and the cold water coming to supply the boiler, surrounding it on all sides, imbibes its heat, by which means the boiler is fed with water of a much higher temperature, and the steam is condensed in H, by which a more rapid exit is obtained for it.

This kind of engine was expressly intended for working carriages. A locomotive engine was made by Mr Trevitheck, in South Wales, in 1804, and was tried upon the rail-roads at Merthyr Tydvall. It drew after it as many carriages as carried ten tons of bar iron for a distance of nine miles, without any further supply of water than that contained in the boiler at setting out, travelling at the rate of five miles per hour. Since that period they have been tried in many places upon rail-roads, but their introduction had not become general until 1811, when Mr Blenkinsop, proprietor of the Middleton Coal-works, which supply the town of Leeds, adopted them for conveying the coals on his rail-road. Mr Blenkinsop, when he adopted the locomotive engine, took up the common rails on one side of the whole length of the road, and replaced them with rails which had cogs on their upper surface. These cogs are cast at the same time with the rails, and are hollow beneath, to be as light as is consistent with strength and durability. The pitch of the cogs is six inches, so that each rail of three feet in length has only six cogs. A wheel which is fixed on an axis which would be that of the fly-wheel at one side of the carriage, works in the teeth of these rails; the whole machine is thus caused to advance along the railway. Many fruitless attempts have been made to produce an engine capable of moving carriages upon common roads; but before this can be effected, the numerous parts of the engine must be made more compact, and its weight considerably reduced.

Observations on the work, &c. &c. of steam-engines in Cornwall, from August 1811, *to May* 1815, *inclusive, by Messrs Lean.*

Messrs Thomas and John Lean were appointed to the general superintendence; and the different proprietors, as also the regular engineers of the respective mines, engaged to give them every facility and assistance in their power. Their first Monthly Report was for August 1811, and included eight engines, which had in that month consumed 23,661 bushels of coals, and lifted 126,126,000 pounds of water one foot high, with one bushel of coals for each engine, being an average duty of 15,760,000 pounds lifted one foot high with each bushel of coals. In the months of September and October the engines reported were nine, and in November and December twelve: and it now evidently appeared that the regular publication of Messrs Lean's very useful tables had already been attended by some improvements in the condition of the engines; for the average duty for December 1811, extracted from these tables, appears to have been 17,075,000 pounds.

In January 1812, the number of engines reported was fourteen, and by the end of that year they were increased to nineteen; and the average duty performed by all the engines in the last mentioned month had advanced to 18,200,000 pounds.

In 1813, the number of engines included in the Monthly Reports continued to increase, till in December they were 29, and the average work 20,162,000.

During some of the months of 1814, the engines reported were 32, and the average duty performed during December was 19,784,000 pounds lifted one foot high with each bushel of coals.

The table which is subjoined is an abstract from Messrs Lean's Reports, and has been formed by first counting how many engines are reported, as in January 1815, 32 engines; then adding up the column containing the quantity of coals consumed by all the engines during the month, and putting down the amount, 110,824; in like manner adding up the column of pounds lifted by each engine one foot high by one bushel of coals, the amount of which was 637,320,990; and lastly, dividing the latter quantity by 32, the number of engines at work, to obtain the average duty performed, viz. 19,916,250 pounds.

TABLE.

	Number of engines reported.	Bushels of coals consumed by all the engines.	Bushels of coals upon which the report is founded.	Pounds of water lifted one foot high by the coals so reported.	Average of pounds lifted one foot high with each bushel of coals
1811. August	8	23,661	8	126,126,000	15,760,000
September	9	25,237	9	125,164,000	13,900,000
October	9	24,487	9	121,910,000	13,540,000
November	12	30,998	12	189,340,000	15,770,000
December	12	39,545	12	204,907,000	17,075,000
1812. January	14	50,089	14	237,661,409	16,972,000
February	15	54,349	15	260,514,000	17.900,000
March	16	59,140	16	274,222,000	17,138,000
April	16	62,384	16	276,238,000	17,260,000

TABLE *continued.*

	Number of Engines reported.	Bushels of coals consumed by all the engines.	Bushels of coals upon which the report is founded.	Pounds of water lifted one foot high by the coals so reported.	Average of pounds lifted one foot high with each bushel of coals
1812. May	16	51,903	16	273,546,000	17,096,000
June	17	50,410	17	288,076,000	16,940,000
July	17	51,574	17	300,441,000	17,677,000
August	17	44,256	17	314,753,000	18,510,000
September	18	46,536	18	348,396,000	19,355,000
October	18	53,941	18	321,900,000	17,883,000
November	21	57,176	21	381,460,000	18,160,000
December	19	55,784	19	341,803,000	18,200,000
1813. January	19	60,400	19	363,906,000	19,153,000
February	22	58,044	22	438,737,000	19,940,000
March	23	73,862	23	440,642,000	19,157,000
April	23	61,739	23	431,032,000	18,700,000
May	24	58,890	24	463,346,000	19,300,000
June	24	53,110	24	470,157,000	19,590,000
July	23	56,709	23	443,462,000	19,281,000
August	21	50,110	21	416,898,000	19,852,000
September	22	58,008	22	427,148,000	19,415,000
October	26	74,796	26	488,671,000	18,795,000
November	28	77,135	28	537,958,000	19,212,000
December	29	86,273	29	584,721,000	20,162,000
1814. January	28	91,753	28	550,751,000	19,670,000
February	26	78,986	26	536,677,000	20,641,000
March	28	109,904	28	565,406,000	20,193,000
April	29	91,607	29	576,617,000	20,325,000
May	28	79,437	28	569,319,000	20,305,000
June	30	75,343	30	626,669,000	20,888,000
July	27	85,224	27	573,208,000	21,229,000
August	26	70,443	26	545,019,000	20,960,000
September	27	78,167	27	560,608,000	20,763,000
October	32	75,080	32	630,704,000	19,709,000
November	32	82,000	32	637,322,000	19,916,000
December	29	84,669	29	573,744,006	19,784,276
1815. January	32	110,824	32	637,320,990	19,916,250
February	33	101,667	33	710,271,250	21,523,370
March	34	117,842	34	706,071,990	20,766,820
April	35	105,701	35	695,212,340	19,863,210
May	34	107,530	34	669,299,140	20,479,350

From the foregoing table it appears that the average duty of the engines reported, exclusive of Woolf's patent engine, is at this time about 20 millions.

We have purposely omitted Woolf's patent engine, because one of the ends intended to be gained by the Monthly Report of work actually done by the engines employed in the mines, particularly in pumping, was to know the comparative merit of Woolf's engine with two cylinders when contrasted with the steam-engines in common use. One of Mr Woolf's engines has been lately erected at Wheal Vor mine, of 53 inches diameter in the great cylinder, (the smaller cylinder being about one-fifth of the contents of the great one,) and nine feet stroke. According to Messrs Lean's Report for May, the duty performed by the engine alluded to, was 49,980,882 pounds lifted one foot with every bushel of coals consumed; and by letter we are informed, (for the printed Report has not yet reached us,) that the duty performed by Woolf's engine in the month of June was 50,333,000.

Thus it appears that the average duty of the patent engine for the months of May and June was fifty millions, while the aggregate average duty of the other engines is only twenty millions. From this it is evident that Mr Woolf's improvements on the steam-engine will be productive of much benefit to the mining interests of the kingdom. On some of the large mines, when this engine shall have come into general use, which it must do sooner or later, the saving in fuel only will add to the yearly dividends among the proprietors several thousand pounds sterling. Nor is this all; the expense that will thus be saved will prevent numbers of mines from stopping work; and will be the means of setting many again to work which have ceased on account of the expense necessary to keep them free from water.

By Messrs Lean's Report for January, (1816,) the average work of 33 engines was 20,694,630 pounds of water lifted one foot high for each bushel of coals consumed. Woolf's engine at Wheal Vor during the same month lifted 47,900,333 pounds, and his engine at Wheal Abraham 47,622,040 pounds one foot high with each bushel of coals.

By the Report for February, the average work of 34 engines was 20,667,398 pounds lifted one foot with each bushel of coals. Woolf's engine at Wheal Vor lifted 45,493,303; and the one at Wheal Abraham 45,896,382 pounds one foot high with each bushel.

Having examined into the construction of the several kinds of engines in general use, we shall forbear to mention the steps of every speculatist who has attempted improvements in this machine, and which have for years filled our periodical publications with plans, possessing more or less ingenuity.

Calculations with respect to the power of steam are of great importance; but practical people are well aware that they cannot be attended with accuracy. We have already shown that the amount of actual force expended in steam-pressures, can be ascertained with great accuracy, by gauges and safety-valves; but the resulting disposable power is not so easily discovered, as the friction of the various parts vary greatly according to the state which they are in. The state of the condensation, in condensing engines, gives a more or less perfect vacuum, which will vary notwithstanding the utmost vigilance. It has been generally set down, among engineers, that nearly one-half of the power of steam must be deducted from the disposable force; therefore, suppose an engine of 24 inch piston, the area of which will be 452 square inches, has a perfect vacuum, as exhibited by the barometer of the condenser, and the weight of the atmosphere, denoted by the weather-barometer, be about fourteen pounds, and the steam-gauge on the boiler stands at about two inches, which is an indication of two pounds pressure, we may estimate that there is 17 lbs. per square inch pressing upon the piston; therefore $17 \times 452 = 7684$ lbs. on the piston, half of which being deducted for allowance of friction, leaves a disposable force of 3842 lbs. moving through the distance at the same rate in which the piston moves; which force being divided by Messrs Bolton and Watt's estimate of a horse-power, will give the nominal power of such engine. In high-pressure engines where the steam is not condensed, what is indicated by the steam-gauge of the boiler only, must be estimated as the power acting upon the piston.

That the increments of power take place in a quicker ratio than those of the temperature, has been long known; and an ingenious mechanic of the present day has attempted to use steam at very high pressures. Without entering into a description of the obstacles he met with, we will briefly observe, that the requisite strength of the parts to withstand the pressure, conjoined to the excessive heat, present obstacles not easily to be overcome.

The reciprocating motion in steam-engines is a loss of power which cannot be denied. For the momentum of the beam and other parts passing in one direction have suddenly to be arrested and moved in the opposite direction, which produces a loss of power. Rotatory action has been sought, therefore, with propriety, but has not yet been obtained with advantage.

Messrs Boulton and Watt, in the introduction of the steam-engine into many works, where the power of horses was used, were obliged to take into consideration the number of horses used for any particular purpose, in order to ascertain the amount of force wanted. Upon the conclusion of a numerous set of experiments they decided, that a horse, working eight hours a day, was capable of raising 33,000 lbs. one foot high, in a minute. Therefore, by dividing the number of pounds an engine can lift one foot high in a minute, it will give the amount of horses' power to which that engine is equal.

An entire view of an engine of the construction termed portable, is represented at fig. 207. A is the cylinder, B the air-pump, C the cold-water pump, D the hot-water pump, E the beam, F the connecting rod, G the fly-wheel, H the eccentric shaft, and I the governor.

It would occupy many volumes to describe the various forms of construction of engines which have, since the knowledge of the power of steam, been contrived; and the information such descriptions would convey would be, comparatively speaking, of very little value, as the majority of them have arisen from men ignorant of the principles of the action of the machine, and whose production should be classed as futile alterations.

In attempting any improvements, the principles of action should first be taken into consideration. In condensing engines the movement is effected by the alternate increase and decrease of temperature, the perfection of both of which is of great importance. The primary point to be aimed at, therefore, is the maintaining of high temperature whilst the steam is forcing, and reducing it suddenly when the condensation is to be effected. This was taken into consideration in the construction of Newcomen's engine, and was most effectually attained by Mr Watt.

The other part of the engine may be examined with a view of improvement, by considering their weight and friction, and by the substituting of a rotatory instead of a reciprocating motion.

Simplicity of construction cannot be too strongly recommended in all mechanical combinations; for there are many contivances which would certainly by deserving of the name of improvements, were they not inapplicable on account of their intricacy.

Attempts have frequently been made to avoid the use of the air-pump, which takes up a considerable portion of the power of an engine. A water barometer, adapted to the condenser, has been sometimes adopted; and a fall of water has been made to pass over the upper edges and down the orifice of a tube, forcing the air before it. The upper end of this tube communicates with the eduction pipe, and is said to support a vacuum of considerable rarity. Exposing the steam which is to be condensed to an increased surface by passing it along

PORTABLE STEAM ENGINE.

207. p. 211

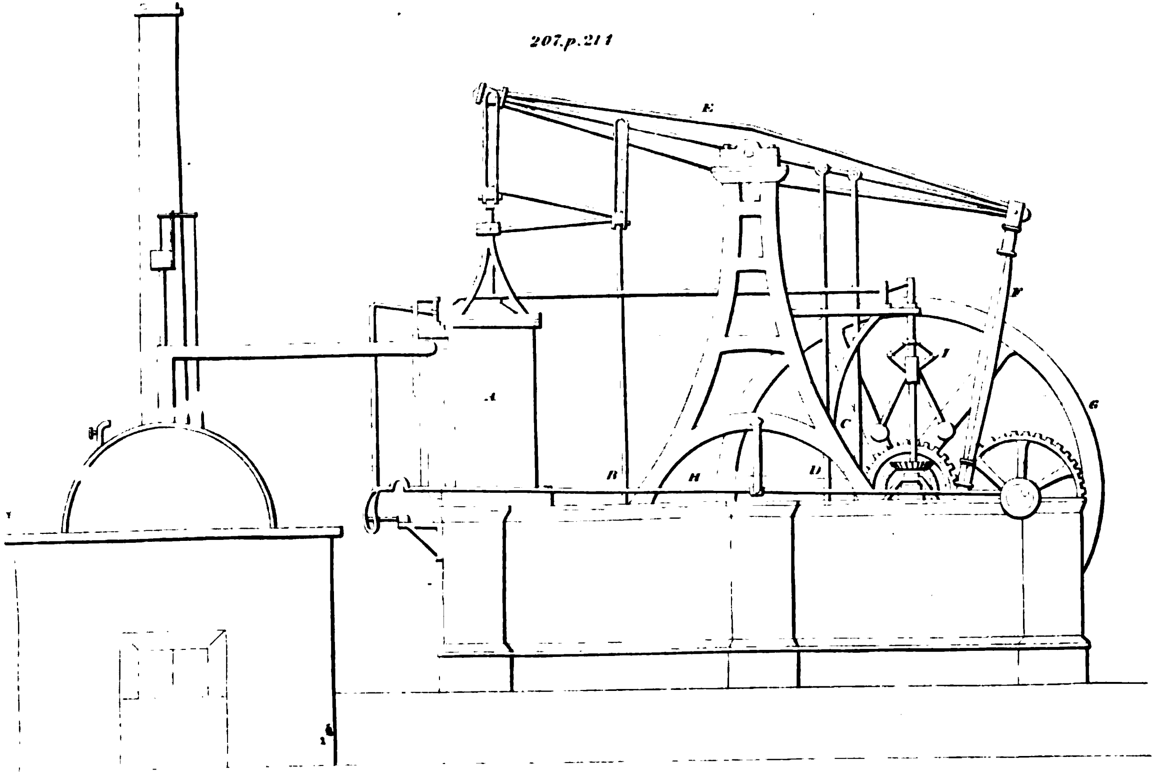
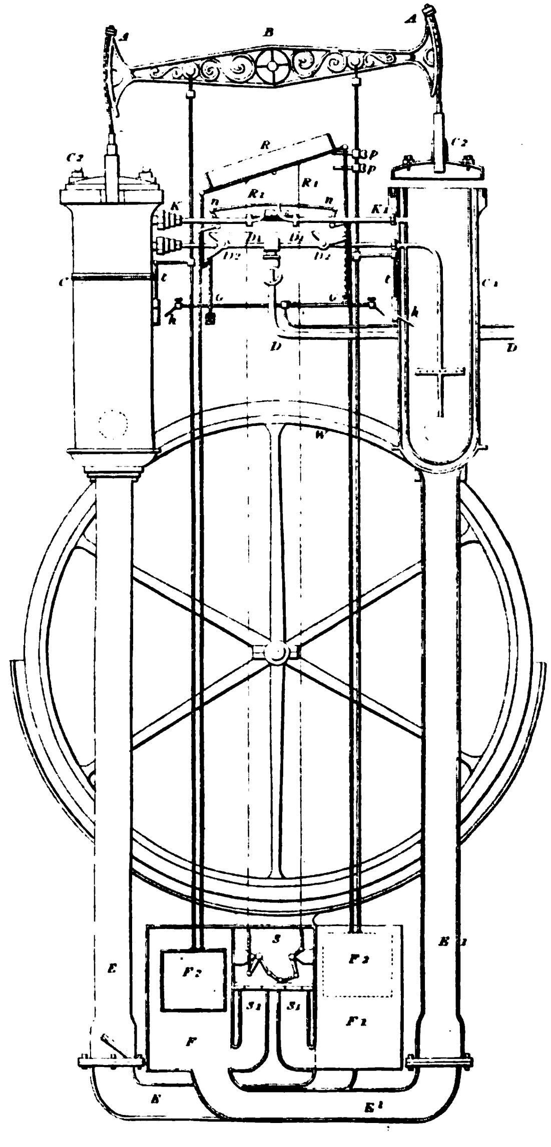


Fig. 208
p. 216


A
B
A
R
C2
C2
p
p
R1
R1
n
n
K
K1
D1
D1
D2
D2
C
t
t
C1
G
G
h
h
D
D
W
E
E1
F2
F2
S
S1
S1
F
F1
E
E1

tubes surrounded by water, or amongst tubes containing water, has likewise been frequently adopted. Indeed the exposure of considerable surface to receive heat in the generation of steam, and the same to abstract it in condensation, have been subjected to frequent trial. That an advantage is to be procured by the adoption of such plans is undoubted; but to attain such increased surface an intricacy in the parts, we fear, must be adopted, which will more than counterbalance the advantages gained.

The valves, or those parts of an engine which direct the distribution of the steam, have always had the attention of engineers, and, as we have shown, many elegant combinations have resulted from their ingenuity.

In running a steam-engine, attention should be given to the working parts. The cylinder should be packed with clean hemp and the best tallow, and frequently examined to see that the packing is in order. The steps of the fly-wheel, shaft, and of the crank, beam, &c. should be frequently examined, and kept well oiled with sperm oil, which is the best for all machinery. These parts must be kept from dust, and if dry grindstones are driven in the mill, the dust must be carefully boxed off from the engine. The use of sand on the floor of an engine-house should, for the same reason, be dispensed with.

The method of starting an engine is, first to shut the condensing cock, then to open all the valves to let the steam pass into the jacket, into the cylinder, through the eduction pipe into the condenser, and out at the blow-valve, in order to expel the air from all the parts, and get them to a proper temperature, which will be shown by the steam issuing from the blow-valve; for previously to the parts being sufficiently warmed, the steam in its progress becomes condensed.

When all the parts are heated, the injection water may be let on, and a vacuum procured on one side of the piston, which produces instant action.

The lever of the throttle-valve, which is ultimately to be attached to the governor, should, on starting the engine, be held by the hand of the attendant until the work is thrown on, and the engine has acquired regular motion.

BROWN'S VACUUM, OR PNEUMATIC ENGINE.

Having concluded our account of the steam-engine, we shall now proceed to give a description of the engine abovementioned, which has recently claimed much attention from the mechanical part of society. It is represented in fig. 208.

A A a beam, capable of vibrating upon a centre at B.

C and C 1 two chambers, formed of metal, of sufficient strength to resist the pressure of the atmosphere, (about 14 lbs. to the square inch,) upon its external surface, and having the caps C 2 C 2 suspended, one at each end of the beam, capable of closing each of these chambers in an air-tight manner. The chamber C 1 is shown in section.

E E and E 1 E 1 are two pipes, containing valves opening upwards, leading and affording a communication from the vessels F and F 1 with each of the chambers C and C 1. These vessels, F and F 1, contain floats, F 2 F 2, attached to the beam A A, by rods which receive motion from the floats; to these rods are attached the slides *t t*, to close alternately, at each vibration of the beam, the apertures *h h*. The pins *p p*, attached to one of the rods from the floats, give motion to the small vibrating tube R, which by the rods R 1 R 1 attached to the cranks in the chamber S, alternately opens and closes the pipes S 1 S 1, communicating with the vessels F and F 1.

D D is a pipe leading from the gasometer, branching off at D 1 D 1 into the two chambers C and C 1, for the purpose of supplying the gas that is to be consumed in effecting the vacuum. This supply can be admitted or shut off by means of the cocks D 2 D 2, which open and close by cranks, worked by the movement of the beam.

G G two other branch-pipes, supplied with gas from the gasometer, and ending in a jet at each end. By the slanting direction of the ends, it is evident, that the flames from these jets will, when their respective orifices *h h* be open, protrude into the chambers C and C 1.

K and K 1 are two pipes, affording a communication from the outer air to the interior of each of the chambers C and C 1; their outer ends are capable of being closed by means of the cranks *n n*, which are attached by chains to the floats F 2 F 2

The mode of operation consists in allowing the gas to pass from the gasometer along one of the branches of the pipe D D, and thence into one of the chambers C or C 1, (suppose C 1,) where, by the jet of ignited gas playing in the orifice *h*, it becomes ignited, and by its combustion rarefies and expels a considerable portion of the atmospheric air from that chamber. Suppose now the cap of the chamber be put down, and by the movement of the rod attached to the float the orifice *h* and gas-pipe D be closed, the combustion will immediately cease, and leave therein a partial vacuum. The atmosphere beginning now to press upon the vessel F, will cause so much of the water to pass from it into the chamber C 1 as will nearly compensate the vacuum, when the valve through which the water passed being closed, and communication between the interior of the chamber and the open air effected by the opening of K 1, the water contained in the chamber flows from thence through the aperture *u*, and affords power, by its fall and weight, to the overshot water-wheel W. From hence it passes into the vessel S, and finally is admitted by S 1 S 1 into F or F 1, leaving the engine in a condition to renew the operation.

By inspecting the plate it will be seen, that when the cap of one chamber crosses, the several openings to the same chamber close with it; and by the rising of the other end of the beam the similar openings to the other chamber are opened, and prepared for a like operation. It will also be seen that the production of this motion is attained by the rising of the two floats in the chambers F and F^1.

The advantages to be derived from this engine, as detailed in the descriptive outline of the inventor, are,

First, "The quantity of gas consumed being very small, the expense of working the engine is moderate. In its application on land the saving will be extremely great, the cost of the coal gas, (deducting the value of the coke,) being inconsiderable. The expense of working a marine engine will certainly be greater, as the gas used for that purpose must be extracted from oil, pitch, tar, or some other substance equally portable, yet even in this case, it will not equal the cost of the fuel required to propel a steam-boat; and as a few butts of oil will be sufficient for a long voyage, vessels of the largest tonnage may be propelled to the most distant parts of the world.

Secondly, "The engine is light and portable in its construction, the average weight being less than *one-fifth* the weight of a steam-engine, (and boiler,) of the same power. It also occupies a much smaller space, and does not require the erection of so strong a building, nor of a lofty chimney. In vessels, the saving of tonnage will be highly advantageous, both in the smaller comparative weight and size of the engine, and in the very reduced space required for fuel.

Thirdly, "This engine is entirely free from danger. *No boiler being used*, explosions cannot take place, and as the quantity of gas consumed is so small, and the only pressure that of the atmosphere, it is impossible that the cylinder can burst, or the accidents incidental to steam-boats occur.

"The power of the engine, (being derived from the atmosperic pressure of ten pounds and upwards upon the square inch,) may be increased with the dimensions of the cylinders, to any extent, and always ascertained by a mercurial gauge.

"It is scarcely necessary to allude to the well-known fact, that, after deducting the friction arising from the use of the air and cold-water pumps, &c. &c. the general *available* power of the condensing steam-engine is from seven to eight pounds per square inch.

"The cost of the machine will be more, *particularly as constructed for raising water*; it is therefore peculiarly adapted for draining fens, &c. or supplying reservoirs. The expense of wear and tear will also be considerably less than that of the steam-engine, and when occasionally out of order, it may be repaired at a trifling cost, and with but little delay."

In examining the effects of this engine, we cannot to a certain extent withhold our approbation; for the patentee has undoubtedly effected and applied a vacuum, produced by ignition, in a manner different and more manageable than any attempts that have hitherto come to our knowledge. The probability of its entering efficiently into competition with the steam-power, is a question that requires the data of experience, which, in this early state of the invention, cannot be procured.

We understand it is the intention of the inventor to apply the effects of the vacuum thus produced to the movement of a piston in a cylinder, which object will, when attained, afford a much greater scope for the application of its powers, and render it peculiarly applicable to locomotion. The obstacle which at present suggests itself to the attainment of this end is, the difficulty of procuring a rapid condensation without allowing cold water to enter the cylinders at each stroke, which in the present form of construction is allowed, and which greatly aids the operation by keeping the chambers entirely cool. Without, however, seeking for obstacles, we wish the ingenious inventor success in surmounting them.

ON THE STRENGTH OF MATERIALS.

An accurate knowledge of the following experiments made by Mr George Rennie, Jun. and communicated by him in a letter to Thomas Young, M.D. For. Sec. R.S. is of so much importance in the construction of machines, that we have extracted it from the *Transactions of the Royal Society*, to which we have annexed some useful notes by Mr T. Tredgold.

"In presenting the result of the following experiments," says Mr Rennie, "I trust I shall not be considered as deviating from my subject, in taking a cursory view of the labours of others. The knowledge of the properties of bodies which come more immediately under our observation, is so instrumental to the progress of science, that any approximation to it deserves our serious attention. The Royal Society appears to have instituted, at an early period, some experiments on this subject, but they have recorded little to aid us. Emerson, in his Mechanics, has laid down a number of rules and approximations. Professor Robison in his excellent treatise in the *Encyclopædia Britannica*, Banks on the Power of Machines, Dr Anderson of Glasgow, Colonel Beaufoy, &c. are those, amongst our countrymen, who have given the result of their experiments on wood and iron. The subject, however, appears to have excited considerable attention on the continent. A theory was published in the year 1638, by Galileo, on the resistance of solids, and subsequently by many other philosophers. But however plausible these investigations appeared, they were more theoretical than practical, as will be seen in the sequel. It is only by deriving a theory from careful and well directed experiments, that practical results can be obtained. It would be useless to enumerate the labours of those philosophers, who, in following, or varying from the steps of Galileo, have merely tended to obscure a subject respecting which they had no data to proceed upon. It is sufficient to enumerate the names of those who, in conjunction with our own countrymen, have added their labours to the little knowledge we possess. The experiments of Buffon, recorded in the *Annals of the Academy of Sciences at Paris*, in the years 1740 and 1741, were on a scale sufficiently large to justify every conclusion, had he not omitted to ascertain the direct and absolute strength of the timber employed. It however appeared from his experiments, that the strength of the ligneous fibre is nearly in proportion to the specific gravity. Muschenbroek, whose accuracy (it is said) entitled him to confidence, made a number of experiments on wood and iron, which, by being tried on various specimens of the same materials, afforded a mean result considerably higher than other previous authorities. Experiments have also been made by Mariotte, Varignon, Perronet, Ramus, Rondelet, Gauthey, Navier, Aubrey and Texier de Norbeck, as also at the *Ecole Polytechnique*, under the direction of M. Prony. With such authorities before us, it might be deemed presumption in me, to offer you a communication on a subject which had been previously treated of by so many able men.* But whoever has had occasion to investigate the principles upon which any edifice is constructed, where the combination of its parts are more the result of uncertain rules than sound principle, will soon find how scanty is our knowledge on a subject, so highly important. The desire of obtaining some approximation, which could only be accomplished by repeated trials on the substances themselves, induced me to undertake the following experiments.

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* It is true that the subject has been considered by many able philophers, from Galileo down to the present period, but it is only lately that the proper object of attention has been ascertained; or at least the results of their inquiries had not been brought forward in a practicable form. For when Dr T. Young published his Lectures, there was little on the subject besides the intricate, and I may add unsatisfactory, investigations of Euler and Lagrange. As to the resistance to fracture, which with the greater part

A bar of the best English iron, about ten feet long, was selected and formed into a lever, whose fulcrum is denoted by *f*, fig. 209. The hole was accurately bored, and the pin turned, which suffered it to move freely. The standard A was firmly secured by the nut *c* to a strong bed plate of cast-iron, made firm to the ground. The lever was accurately divided in its lower edge, which was made straight in a line with the fulcrum. A point, or division D, was selected, at five inches from the fulcrum, at which place was let in a piece of hardened steel. The lever was balanced by a weight, and in this state it was ready for operation. But in order to keep it as level as possible, a hole was drilled through a projection on the bed plate, large enough to admit a stout bolt easily through it, which again was prevented from turning in the hole by means of a tongue *t* fitting into a corresponding groove in the hole. So that, in order to preserve the level, we had only to move the nut to elevate or depress the bolt, according to the size of the specimen. But as an inequality of pressure would still arise from the nature of the apparatus, the body to be examined was placed between two pieces of steel, the pressure being communicated through the medium of two pieces of thick leather above and below the steel pieces, by which means a more equal contact of surfaces was attained. The scale was hung on a loop of iron, touching the lever in an edge only. I at first used a rope for the balance weight, which indicated a friction of four pounds, but a chain diminished the friction one-half. Every movable centre was well oiled. Of the resistances opposed to the simple strains which may disturb the quiescent state of a body, the principal are the repulsive force, whereby it resists compression, and the force of cohesion, whereby it resists extension. On the former, with the exception of the experiments of Gauthey and Rondelet, on stones, and a few others, on soft substances, there is scarcely any thing on record. In the memoir of M. Lagrange, on the force of springs, published in the year 1760, the moment of elasticity is represented by a constant quantity, without indicating the relation of this value to the size of the spring: but in the memoir of the year 1770, on the forms of columns, where he considers a body whose dimensions and thickness are variable, he makes the moment of elasticity proportional to the fourth power of the radius, in observing the relations of theory and practice to accord with each other. This

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of mechanical writers is the only object attended to, it is of very inferior importance.

The laws of flexure constitute the chief guide in the construction of buildings; and the intention of these notes is to call the attention of experimentalists to this part of the subject; and as it is probable the ingenious author of the experiments now before me may be tempted to resume his labours, I feel certain that he will not feel displeased to have his attention called to some interesting points of inquiry, which he has either neglected to notice, or has not given to the public.—T. T.

was admitted by Euler in his memoir of 1780, in his elaborate investigation of the forms of columns. Mr. Coulomb had however shown before that time, how inapplicable all these calculations were to columns under common circumstances; and you, sir, have repeated the observation in your lectures on natural philosophy. The results of experiments have also been equally discordant; since it is deduced from those of Reynolds, that the power required to crush a cubic quarter of an inch of cast-iron is 448000 pounds avoirdupoise, or 200 tons; whereas by the average of thirteen experiments made by me on cubes of the same size, the amount never exceeded 10392.53 lbs. not quite five tons. This may be seen by referring to the tables. There were four kinds of iron used, viz. 1. Iron taken from the centre of a large block, whose crystals were similar in appearance and magnitude to those evinced in the fracture of what is usually termed gun-metal. 2. Iron taken from a small casting, close grained, and of a dull grey colour. 3. Iron cast horizontally in bars of three-eighths of an inch square, 8 inches long. 4. Iron cast vertically, same size as last. These castings were reduced equally on every side to ¼ of an inch square: thus removing the hard external coat usually surrounding metal castings. They were all subjected to a gauge. The bars were then presumed to be tolerably uniform. The weights used were of the best kind that could be procured, and as the experiment advanced, smaller weights were used.

Experiments on cast-iron in cubes of ⅛ of an inch, &c.

Iron taken from the block whose specific gravity was 7.033

Averages.			lbs. avoir.
1439.66	$\frac{1}{8}\times\frac{1}{8}$		1454
	$\frac{1}{8}\times\frac{1}{8}$		1416
	$\frac{1}{8}\times\frac{1}{8}$		1449

On specimens of different lengths. Specific gravity of iron 6.977.

2116	$\frac{1}{8}\times\frac{2}{8}$		1922
	$\frac{1}{8}\times\frac{2}{8}$		2310
1758.5	$\frac{1}{8}\times\frac{3}{8}$	slipped with 1863 lbs. filed flat, and crushed with	2263
	$\frac{1}{8}\times\frac{4}{8}$	ditto - 1495 ditto	2005
	$\frac{1}{8}\times\frac{5}{8}$	ditto	1407
	$\frac{1}{8}\times\frac{6}{8}$	ditto	1743
	$\frac{1}{8}\times\frac{7}{8}$	ditto	1594
	$\frac{1}{8}\times\frac{8}{8}$	ditto	1439

April 23, 1817. *Experiments on cubes of ¼ of an inch taken from the block.*

9773.5	$\frac{1}{4}\times\frac{1}{4}$		10561
	$\frac{1}{4}\times\frac{1}{4}$		9596
	$\frac{1}{4}\times\frac{1}{4}$		9917
	$\frac{1}{4}\times\frac{1}{4}$		9020

Castings, horizontal. Specific gravity 7.113.

10114	$\frac{1}{4}\times\frac{1}{4}$		10432
	$\frac{1}{4}\times\frac{1}{4}$		10720
	$\frac{1}{4}\times\frac{1}{4}$		10605
	$\frac{1}{4}\times\frac{1}{4}$		8699

Vertical castings. Specific gravity 7.074.

11136.75	$\frac{1}{4}\times\frac{1}{4}$	bottom of vertical bar	12665
	$\frac{1}{4}\times\frac{1}{4}$		10950
	$\frac{1}{4}\times\frac{1}{4}$		11088
	$\frac{1}{4}\times\frac{1}{4}$		9844
	$\frac{1}{4}\times\frac{1}{4}$	full size. Scale broke with 10294; tried again	11006

Averages.			lbs. avoir.
	A prism, having a logarithmic curve for its limits, resembling a column; it was ¼ of an inch diameter by one inch long, broke with		6954

April 28th. Trials on prisms of different lengths.

9414.5	$\frac{1}{4}\times\frac{1}{2}$	horizontal	9455
	$\frac{1}{4}\times\frac{1}{2}$	ditto	9374
	$\frac{1}{4}\times\frac{1}{2}$	ditto, bad trial, 9006 lbs.	
9982.5	$\frac{1}{4}\times\frac{1}{2}$	vertical	9938
	$\frac{1}{4}\times\frac{1}{2}$	ditto	10027

April 29th. Horizontal Castings.

$\frac{1}{4}\times\frac{4}{8}$		9006
$\frac{1}{4}\times\frac{5}{8}$		8845
$\frac{1}{4}\times\frac{6}{8}$		8362
$\frac{1}{4}\times\frac{7}{8}$		6430
$\frac{1}{4}\times\frac{8}{8}$	or one inch long	6321

Vertical Castings.

$\frac{1}{4}\times\frac{4}{8}$		9328
$\frac{1}{4}\times\frac{5}{8}$		8385
$\frac{1}{4}\times\frac{6}{8}$	a small defect in the specimen	7896
$\frac{1}{4}\times\frac{7}{8}$		7018
$\frac{1}{4}\times\frac{8}{8}$	or one inch	6430

Experiments on different metals.

$\frac{1}{4}\times\frac{1}{4}$	cast copper, crumbled with				7318
$\frac{1}{4}\times\frac{1}{4}$	fine yellow brass reduced	$\frac{1}{10}$	with 3213.	½ with	10304
$\frac{1}{4}\times\frac{1}{4}$	wrought copper	$\frac{1}{16}$	3427.	⅛	6440
$\frac{1}{4}\times\frac{1}{4}$	cast tin	$\frac{1}{16}$	552.	½	966
$\frac{1}{4}\times\frac{1}{4}$	cast lead			½	483

The anomaly between the three first experiments on ⅛ cubes, and the two second of a different length, can only be accounted for, on the difficulty of reducing such small specimens to an equality. The experiments on ⅛ inch prisms of different lengths give no ratio. The experiments on ¼ inch cubes, taking an average of the three first in each, give a proportion between them and the three on ⅛ cubes,

as 1 : 6.096 in the block castings
as 1 : 7.352 in the horizontal ditto
as 1 : 8.035 in the vertical ditto.

In several cases the proportion is as the cubes.

The vertical cube castings are stronger than the horizontal cube castings.

The prisms usually assumed a curve similar to a curve of the third order previous to breaking.

The experiments on the different metals give no satisfactory results. The difficulty consists in assigning a value to the different degrees of diminution. When compressed beyond a certain thickness, the resistance becomes enormous.

Experiments on the suspension of bars.

The lever was used as in the former case, but the metals were held by nippers. They were made of wrought iron, and their ends adapted to receive the bars, which, by being tapered at both extremities, and increasing in diameter from the actual section, (if I may so express it,) and the jaws of the nippers being confined by a hoop, confined both. The bars, which were six inches long, and ¼ square, were thus fairly and firmly grasped.

April, 30, 1817.

No.			
45	¼ inch, cast iron bar, horizontal - -	1166	1193.5 lbs.
46	¼ do do vertical - -	1218	
47	¼ do cast steel previously tilted -	8391	
48	¼ do blister steel, reduced per hammer	8322	
49	¼ do shear steel, do do - -	7977	
50	¼ do Swedish iron, do do - -	4504	
51	¼ do English iron, do do - -	3492	
52	¼ do hard gun-metal, mean of two trials	2273	
53	¼ do wrought copper, reduced per hammer	2112	
54	¼ do cast copper, - - - - -	1192	
55	¼ do fine yellow brass - - - -	1123	
56	¼ do cast tin - - - - - - -	296	
57	¼ do cast lead - - - - - - -	114	

Remarks on the last experiments.

The ratio of the repulsion of the horizontal cast cubes to the cohesion of horizontal cast bars, is 8.65 : 1.

The ratio of the vertical cast cubes to the cohesion of the vertical cast bars, is as 9.14 : 1.

The average of the bars, compared with the cube, No. 16, is as 10.611 : 1.

The other metals decrease in strength, from cast steel to cast lead.

The stretching of all the wrought bars indicated heat.

The fracture of the cast bars was attended with very little diminution of section, scarcely sensible.

The experiment made by M. Prony, (which asserts, that by making a slight incision with the file, the resistance is diminished one-half,) was tried on a ¼ inch bar of English iron; the result was 2920 lbs. not a sixth part less.

This single experiment, however, does not sufficiently disprove the authority of that able philosopher, for an incision is but a vague term. The incision I made might be about the fortieth part of an inch.

Experiments on the twist of ¼ inch bars.

To effect the operation of twisting off a bar, another apparatus was prepared: it consisted of a wrought-iron lever two feet long, having an arched head about 1-6th of a circle, of four feet diameter, of which the lever represented the radius; the centre round which it moved had a square hole made to receive the end of the bar to be twisted. The lever was balanced as before, and a scale hung on the arched head; the other end of the bar being fixed in a square hole in a piece of iron, and that again in a vice. The undermentioned weights represent the quantity of weight put into the scale.

May 30, 1817.

On twists close to the bearing, cast horizontal.

No.		lbs.	oz.	
58	¼ in bars, twisted as under with - -	10	14	in the scale.
59	¼ do bad casting - - - - - - -	8	4	
60	¼ do - - - - - - - - -	10	11	
	Average	9	15	
	Cast vertical.			
61	¼ - - - - - - - - -	10	8	
62	¼ - - - - - - - - -	10	13	
63	¼ - - - - - - - - -	10	11	
	Average	10	10	

On different metals.

No.		lbs.	oz.	
64	Cast steel	17	9	in the scale.
65	Sheer steel	17	1	
66	Blister steel	16	11	
67	English iron, wrought	10	2	
68	Swedish iron wrought	9	8	
69	Hard gun-metal	5	0	
70	Fine yellow brass	4	11	
71	Copper, cast	4	5	
72	Tin	1	7	
73	Lead	1	0	

On twists of different lengths.

Horizontal.			Vertical.		
No.	Weight in scale.		No.	Weight in scale.	
74 ¼ by ½ long	7	3	77 ¼ by ½ do.	10	1
75 ¼ by ¾ do.	8	1	78 ¼ by ¾ do.	8	9
76 ¼ by 1 inch do.	8	8	79 ¼ by 1 inch do.	8	5

Horizontal twists at 6 from the bearing.

80 ¼ by 6 inches long	10	9
81 ¼ by do. do.	9	4
82 ¼ by do. do.	9	7

Twists of ½ inch square bars, cast horizontally.

No.	qrs.	lbs.	oz.	
83 ½ close to the bearing	3	9	12	end of the bar hard.
84 ½ do.	2	18	0	middle of the bar.
85 ½ at 10 inches from bearing, lever in the middle	1	24	0	

On twists of different materials.

These experiments were made close to the bearing, and the weights were accumulated in the scale until the substances were wrenched asunder.

No.	Weight in scale.		No.	Weight in scale.	
86 Cast steel	19	9	91 Hard gun metal	5	0
87 Shear steel	17	1	92 Fine yellow brass	4	11
88 Blister steel	16	11	93 Copper	4	5
89 English iron, No. 1	10	2	94 Tin	1	7
90 Swedish iron	9	8	95 Lead	1	0

Remarks.

Here the strength of the vertical bars still predominates.

The average of the two taken conjointly, and compared with a similar case of ½ inch bars, gives the ratio as the cubes, as was anticipated.

In the horizontal castings of different lengths, the balance is in favour of the increased lengths; but in the vertical castings, it is the reverse. In neither is there any apparent ratio. In the horizontal castings at six inches from the bearing, there is a visible increase, but not so great as when close to the bearing.

June 4, 1817. *Miscellaneous experiments on the crush of one cubic inch.*

No.		lbs. avoir.
96	Elm	1284
97	American pine	1606
98	White deal	1928
99	English oak, mean of two trials	3860
100	Ditto, of 6 inches long, slipped with	2572

No.		lbs. avoirdupoise.
101	English oak, of four inches long, slipped with	5147*
102	A prism of Portland stone, 2 inches long	805
103	Ditto, statuary marble	3216
104	Craig Leith	8688

In the following experiments on stones, the pressure was communicated through a kind of pyramid, the base of which rested on the hide leather, and that on the stone.† The lever pressed upon the apex of the pyramid. Cubes of one and a half inch.

No.		Spec. grav.	lbs. avoir.
105	Chalk		1127
106	Brick of a pale red colour	2.085	1265
107	Roe-stone, Gloucestershire		1449
108	Red brick, mean of two trials	2.168	1817
109	Yellow face baked Hammersmith paviors, 3 times		2254
110	Burnt do. mean of two trials		3243
111	Stourbridge or fire brick		3864
112	Derby grit, a red friable sand-stone	2.316	7070
113	Ditto from another quarry	2.428	9776
114	Killaly white free-stone, not stratified	2.423	10264
115	Portland	2.428	10284
116	Craig Leith, white free-stone	2.452	12346
	June 5, 6, and 7, 1817.		
117	Yorkshire paving with the strata	2.507	12866
118	Ditto do. against the strata	2.507	12856
119	White statuary marble not veined	2.760	13632
120	Bramley Fall sand-sone, near Leeds, with strata	2.506	13632
121	Ditto, against the strata	2.506	13632
122	Cornish granite	2.662	14302
123	Dundee sand-stone or brescia, two kinds	2.530	14918
124	A two-inch cube of Portland	2.423	14918
125	Craig Leith with the strata	2.452	15560
126	Devonshire red marble, variegated	.....	16712
127	Compact lime-stone	2.584	17354
128	Peterhead granite hard close grained	.....	18636
129	Black compact lime-stone, Limerick	2.598	19924
130	Purbeck	2.599	20610
131	Black Brabant marble	2.697	20742
132	Very hard free-stone	2.528	21254
133	White Italian veined marble	2.726	21783
134	Aberdeen granite, blue kind	2.625	24556

N.B. The specific gravities were taken with a delicate balance, made by Creighton of Glasgow, all with the exception of two specimens, which were by accident omitted.

Remarks.

In observing the results presented by the preceding table, it will be seen that little dependence can be placed on the

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[*] The experiments on woods are considerably below those of other writers, and it appears singular that the four-inch specimen should be stronger than the shorter length. According to Rondelet's experiments, to crush a cubic inch of oak it required from 5000 to 6000 lbs. avoirdupoise,
of fir . . from 6000 to 7000 lbs.
In the former the pieces were compressed one-third of their length; in the latter one-half of their length, (Rondelet's *L'Art le Bâtir*, tom. iv. p. 67.) Mr Rennie has not stated the diminution of length.

[†] It certainly would have been preferable to have placed a hard and rigid substance next the stone, in order to secure equality of pressure.

specific gravities of stone, so far as regards their repulsive powers, although the increase is certainly in favour of their specific gravities. But there would appear to be some undefined law in the connection of bodies, with which the specific gravity has little to do. Thus, statuary marble has a specific gravity above Aberdeen granite, yet a repulsive power not much above half the latter. Again, hardness is not altogether a characteristic of strength, inasmuch as the lime-stones, which yield readily to the scratch, have nevertheless a repulsive power approaching to granite itself.

It is a curious fact in the rupture of amorphous stones, that pyramids are formed, having for their base the upper side of the cube next the lever, the action of which displaces the sides of the cubes, precisely as if a wedge had operated between them. I have preserved a number of the specimens, the sides of which, if continued, might cut the cubes in the direction of their diagonals.

Experiments made on the transverse strain of cast bars, the ends loose. June 8th, 1817.*

		Weight of the bars, lbs.	oz.	dist. of bearings. ft.	in.	lbs. avoir.
135	Bar of 1 inch square	12	6	3	0	897
136	Do. of 1 inch do.	9	8	2	8	1086
137	Half the above bar	.....		1	4	2320
138	Bar of 1 inch square, through the diagonal	2	8	2	8	851
139	Half the above bar	.....		1	4	1587
140	Bar of 2 inches deep, by ½ inch thick	9	5	2	8	2185
141	Half the above bar	.....		1	4	4508

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* A bar of cast-iron, from a Welsh foundry, which did not yield easily to the file, was laid upon supports exactly three feet apart; the bar was an inch square, and when 308 pounds were put into a scale suspended from the middle of its length, the deflexion was found to be 3-16ths of an inch; whence the height of the modulus of elasticity is 6,386,688 feet. The experiment was made by Mr R. Ebbels, at Garnons, near Hereford. A joist of cast-iron, nine inches deep, resembling in form the letter I, was laid upon supports 19 feet apart, first on its edge, when the deflexion from its own weight was 3-40ths of an inch. It was then laid flatwise, and the deflexion from its own weight was 3½ inches. The castings were from Messrs Dowsons's foundry, Edgware-road. The iron yielded easily to the file. The height of the modulus of elasticity according to the experiment on the

joist flatwise is 5,100,000 feet,
—— on the edge is 5,700,000 feet.

The deflexion being very small when the joist was on its edge, perhaps it was not measured with the necessary degree of accuracy, as a very small error would cause the difference in the result. The following tablet contains the value of the modulus for cast-iron, according to the experiments above stated.

	Height of modulus in feet.	Experimentalists.
Cast-iron (Welsh)	6,386,688	Ebbels.
Cast-iron	3,500,000	Banks.
Cast-iron, gray French	5,095,480	Rondelet.
Cast-iron, soft do.	4,247,000	Rondelet.
Cast-iron	5,700,000	By my trial.

		Weight of the bars, lbs.	oz.	dis. of bearings. ft.	in.	lbs. avoir.
142	Bar 3 inches deep, by ⅓ inch thick	9	15	2	8	3588
143	half the bar	.....		1	4	6854
144	Bar 4 inches, by ¼ inch thick . .	9	7	2	8	3979
145	Equilateral triangles with the angle up and down.					
146	Edge or angle up	9	11	2	8	1437
147	——— angle down . .	9	7	2	8	840
148	Half the first bar	.....		1	4	3059
149	Half the second bar . . .	.....		1	4	1656
150	A feather-edged or ⊥ bar was cast whose dimensions were					
151	2 inches deep by 2 wide . .	10	0 edge up	2	8	3105
152	half of ditto					

N. B. All these bars contained the same area, though differently distributed as to their forms.

Experiments made on the bar of 4 inches deep by ¼ inch thick, by giving it different forms, the bearings at 2 feet 8 inches, as before.

No.		lbs.	lbs.
153	Bar formed into a semi-ellipse, weighed . .	7	4000
154	Ditto, parabolic on its lower edge . . .		3860
	Ditto, of 4 inches deep by ¼ inch thick . .		3979

Experiments on the transverse strain of bars, one end made fast, the weight being suspended at the other, at 2 feet 8 inches from the bearing.

155	An inch square bar bore	280
156	A bar 2 inches deep by ½ an inch thick	539
157	An inch bar, the ends made fast	1173

The paradoxical experiment of Emerson was tried, which states that by cutting off a portion of an equilateral triangle, (see page 114 of Emerson's Mechanics,) the bar is stronger than before, that is, a part stronger than the whole. The ends were loose at two feet eight inches apart as before. The edge from which the part was intercepted was lowermost, the weight was applied on the base above, it broke with 1129 pounds, whereas in the other case it bore only 840 pounds.

Remarks on the transverse strain.

Banks makes his bar from the cupola, when placed on bearings three feet asunder, and the ends loose, to bear . . . . . . 864 lbs.

Now all my bars were cast from the cupola, the difference was therefore . . . . 33 lbs.

I adopted a space of two feet eight inches asunder, as being more convenient for my apparatus. The strength of the different bars, all cases being the same, approaches nearly to the theory, which makes the comparative values as the breadths multiplied into the squares of the depths. The halves of the bars were tried, merely to keep up the analogy. The bar of four inches deep, however, falls short of theory by 365 pounds. It is evident we cannot extend the system of deepening the bar much further, nor does the theory exactly maintain in the case of the equilateral triangle by . . 243 lbs.

The diagonal position of the square bar, is actually worse than when laid on its side, contrary to many assertions.

The same quantity of metal in the feather-edged bar was not so strong as in the four-inch bar.

The semi-elliptical bar, exceeded the four-inch bar, although taken out of it. The parabolic bar came near it.

The bar made fast at both ends, I suspect must have yielded, although the ends were made fast by iron straps. The experiments from Emerson, on solids of different forms, might be made; but the time and trouble these experiments have already cost, have compelled me to relinquish further pursuits for the present. If, however, in the absence of better, they are worthy of the indulgence of the Royal Society, it will not only be a consolation to me that my labours merit their attention, but a further inducement to prosecute the investigation of useful facts, which, even in the present advanced state of knowledge, will yet admit of addition.

The science of construction is yet in its infancy, and certainly requires many additions. The first experiments on the strength of materials appear to have been made before the Royal Society; and there can be no doubt that a favourable reception will be given to any others that will tend to elucidate a subject which is likely to form one of the principal branches of an engineer's education; as he must either proceed on the principle of science, or be directed by a feeling of fitness, which is to be acquired only by devoting a lifetime to the practice of his art.

HYDRAULIC ENGINES.

This term is applicable to all machines driven by the force of water; consequently we have, under the article "Water-mills," already treated of, the most extensive branch of these machines. Those which have now to claim our attention, are such as could not with propriety be introduced under that head, and which are, upon the whole, of too much importance, both with respect to the conveyance of water, and as accessions to mechanical combinations, to be entirely omitted.

1. Of all the hydraulic machines invented by the ancients, though Archimedes's screw is the most curious, the *tympanum* raises the greatest quantity of water at once.

It consists of a great hollow wheel, composed of several planks joined together, and well calked and pitched, forming, as its name imports, a kind of barrel or drum, and having an horizontal axle on which it turns. The interior is divided by eight partitions into as many equal spaces or cells, each of which has an orifice of about half a foot in the rim of the drum or wheel, shaped so as to facilitate the admission of the water: there are, moreover, eight hollow channels running contiguous to each other and parallel to the axis of the wheel, each corresponding to one of the eight large cells, through which the water passes from the cells just mentioned, and after running along the channels to a convenient distance escapes through orifices into a reservoir placed just beneath the axle of the wheel. Thus the water is elevated through a vertical space equal to the radius of the hollow wheel. When the tympanum is used to raise water from a running stream, it is moved by means of float-boards impelled by the stream; but when employed to raise stagnant water, it receives motion from a foot-wheel placed on the same shaft, which is, as we have already described under the article "Foot-mill," turned by men walking inside. The chief defect of this machine is, that it raises the water in the most disadvantageous situation possible; or the load being found always towards the extremity of a radius of the wheel, the arm of the effective lever which answers to it, increases through the whole quadrant the water describes in passing from the bottom of the wheel to the altitude of its centre; so that the power must act in like manner as if it were applied at a winch-handle; and consequently, cannot act uniformly.

2. *M. de la Faye*, to remedy this defect, devised a machine which may here be described, together with the process of reasoning that led to it.

When we develope the circumference of a circle, a curve is described, (i. e.the involute,) of which all the radii are so many tangents to the circle, and are likewise all respectively perpendicular to the several points of the curve described, which has for its greatest radius a line equal to the periphery of the circle evolved. The truth of which is shown by geometricians when treating of the genesis of evolute and involute curves.

Hence, having an axle whose circumference a little exceeds the height which the water is proposed to be elevated, let the circumference of the axle be evolved, and make a curved canal whose curvature shall coincide throughout exactly with that of the involute just formed; if the further extremity of this canal be made to enter the water that is to be elevated, and the other extremity abut upon the shaft which is turned, then in the course of the rotation the water will rise in a vertical direction, tangential to the shaft, and perpendicular to the canal in whatever position it may be. Thus the action of the weight answering always to the extremity of a horizontal radius, will be as though it acted upon the invariable arm of a lever, and the power which raises the weight will be always the same; and if the radius of the wheel, of which this hollow canal serves as a bent spoke, is equal to the height that the water is to be raised, and consequently equal to the circumference of the axle or shaft, the power will be to the load of water reciprocally as the radius of a circle to its circumference, or directly as 1 to 6¼ nearly.

In *M. de la Faye's* opinion, the machine ought to be composed of four of these canals: but it has often been constructed with eight, as represented in fig. 210. The wheel being turned by the impulsion of the stream upon the float-boards, the orifices F, E, D, C, &c. of the curvilinear canals, dip one after another into the water which runs into them; and as the wheel revolves the fluid rises in the canals *f*, *e*, *d*, *c*, &c. and runs out in a stream P from the holes at O; it is received into the trough Q, and conveyed from thence by pipes.

By this construction the weight to be raised offers always the same resistance, and that the least possible, while the power is applied in the most advantageous manner the circumstances will admit of: these conditions both fulfilled at the same time furnish the most desirable perfection in a machine. Further, this machine raises the water by the shortest way, namely, the perpendicular or vertical; in this respect being preferable to Archimedes's screw, where the water is carried up an inclined path: and besides this, each curved channel in this wheel empties all the water it receives in every revolution, while the screw of Archimedes delivers only a small portion of the fluid it is charged with, being often loaded with twenty times as much water as is discharged in one rotation; and thus requiring an enormous increase of labour when a large quantity is intended to be raised by it.

The nature and advantages of this wheel evince very forcibly how far the speculations of geometers are from being so unfruitful in useful applications, as is often insinuated by practical men.

3. The wheel just described would, we think, be the most perfect of any that could be employed for raising water, had it not the disadvantage attending the tympanum, which is, that it can only raise water to the height of its semidiameter. As in many cases water is to be raised higher than the radius of any wheel can well be made for practice, we shall next describe a machine called the *Noria*, common in Spain, which raises water nearly through a diameter.

This Noria consists of a vertical wheel of 20 feet diameter, on the circumference of which are fixed a number of little boxes or square buckets, for the purpose of raising the water out of the well, communicating with the canal below, and to empty it in a reservoir above, placed by the side of the wheel. The buckets have a lateral orifice, to receive and to discharge the water. The axis of this wheel is embraced by four small beams, crossing each other at right angles, tapering at the extremities, and forming eight little arms. This wheel is near the centre of the horse-walk, contiguous to the vertical axis, into the top of which the horse-beam is fixed: but near the bottom it is embraced by four little beams, forming eight arms similar to those above described, on the axis of the water-wheel. As the mule which they use goes round, these horizontal arms, supplying the place of cogs, take hold, each in succession, of those arms which are fixed on the axis of the water-wheel, and keep it in rotation.

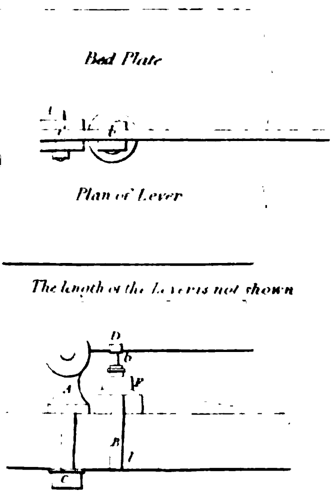
This machine, than which nothing can be cheaper, throws up a great quantity of water; yet undoubtedly it has two defects: the first is, that part of the water runs out of the buckets and falls back into the well after it has been raised nearly to the level of the reservoir: the second is, that a considerable proportion of the water to be discharged is raised higher than the reservoir, and falls into it only at the moment when the bucket is at the highest point of the circle, and ready to descend. These inconveniences are both remedied by the contrivance mentioned in the next paragraph.

4. The *Persian wheel* is a name given to a machine for raising water, which may be turned by means of a stream A B acting upon the wheel C D E according to the order of the letters; (fig. 210.)

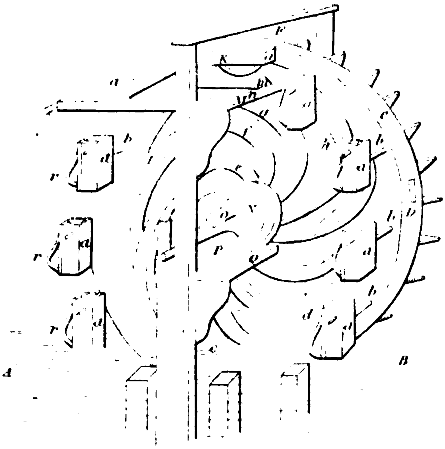
The buckets *a*, *a*, *a*, *a*, &c. instead of being firmly fastened, are *hung* upon the wheel by strong pins, *b*, *b*, *b*, *b*, &c. fixed in the side of the rim; which must be made as high as the water is intended to be raised above the level of the part of the stream in which the wheel is placed. As the wheel turns, the

From 209 to 213

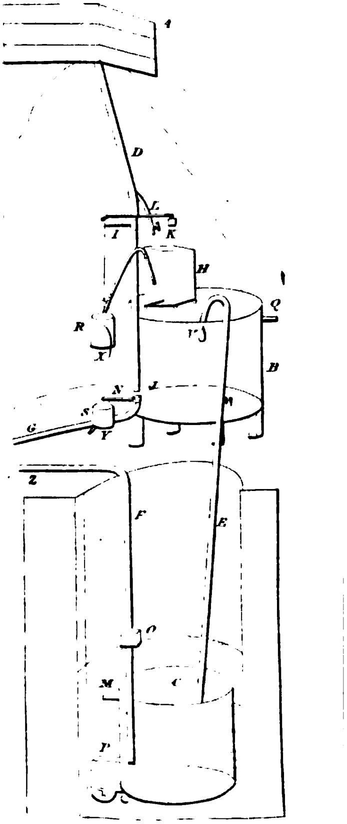
209.p.220



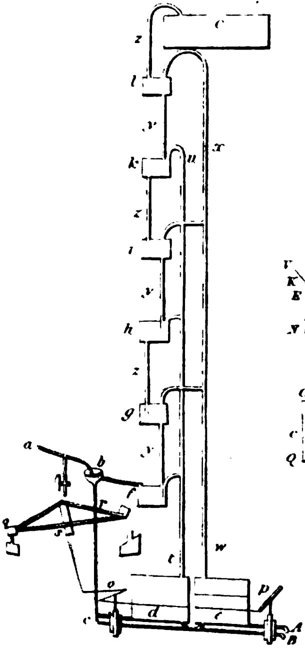
210 p 229



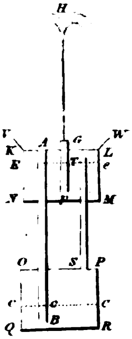
213.p.233, 36



211.p.232



212.p.232



buckets on the right hand go down into the water, where they are filled, and return up full on the left hand, till they come to the top at K; where they strike against the end *n* of the fixed trough M, by which they are overset, and so empty the water into the trough; from whence it is to be conveyed in pipes to any place it is intended for: and as each bucket gets over the trough, it falls into a perpendicular position again, and so goes down empty till it comes to the water at A, where it is filled as before. On each bucket is a spring *r*, which going over the top or crown of the bar *m*, (fixed to the trough M,) raises the bottom of the bucket above the level of its mouth, and so causes it to empty all its water into the trough.

To determine the due relation of the power and the weight so that this wheel may be capable of producing the greatest effect, the following may be taken as a good approximation. After having fixed the diameter of the wheel, which must be something greater than the altitude to which the water is to be raised, fix also upon an even number of buckets to be hung at equal distances round the periphery of the wheel, and mark the position of their centres of motion in such a manner that they will stand in corresponding positions in every quarter of the circle: conceive vertical lines drawn through the centre of motion of each bucket in the rising part of the wheel; they will intersect the horizontal diameter of the wheel in points at which, if the buckets were hung, they would furnish the same resistance to the moving force as they do when hanging at their respective places on the rim of the wheel. Thus, supposing there were 18 equidistant buckets; then while eight hung on each side a vertical diameter of the wheel there would be eight on the other side, and two would coincide with that diameter: in this case the resistance arising from all the full buckets would be the same as if one bucket hung on the prolongation of the horizontal diameter at the distance of $2 \sin. 20° + 2 \sin. 40° + 2 \sin. 60° + 2 \sin. 80°$, these being the sines to the common radius of the wheel.

To know the quantity of water that each bucket should contain, take four-ninths of the absolute force of the stream, that is, four-ninths of the weight of the prism of water whose base is the surface of one of the float-boards, and whose height is that through which water must fall to acquire the velocity of the stream; so have we the power that should be in equilibro with the weight of water in the buckets of the rising semicircle. Then say, as the sum of the sines mentioned above is to radius, so is the power just found to a fourth term, the half of which will be the weight of water that ought to be contained in one bucket. Lastly, as the velocity of the wheel will be to that of the stream nearly as one to two and two-fifths, the quantity of revolutions it makes in any determinate time becomes known, and, by consequence, the quantity of water the wheel will raise in the same time; since we know the capacity of each bucket, and the number of them emptied in every revolution of the wheel.

5. Another contrivance for raising water similar to the chain-pump, which is described in another part of the work, is an endless rope with stuffed cushions hung upon it, which, by means of two wheels or drums, are caused to rise in succession in the same barrel, and to carry water with them. From the resemblance of this apparatus to a string of beads, it is usually called *paternoster-work*. But in this, as well as the chain-pump, the magnitude of the friction is a formidable practical objection.

6. Jets and fountains are not now considered as conducive

to picturesque beauty; nor can they be reckoned of much utility, except perhaps in hot climates; we have not therefore described any in this work. But in the fountain of *Hiero* of Syracuse, a principle is introduced which has been found of great utility in larger works; for the head of water is actually lower than the orifice, but the pressure is communicated by the intervention of a column of air; the construction of this fountain is as follows:

It consists of two vessels K L M N, (fig. 212) and O P Q R, which are close on all sides. A tube A B, having a funnel at the top, passes through the uppermost vessel without communicating with it, being soldered into its top and bottom. It also passes through the top of the under vessel, where it is likewise soldered, and reaches almost to its bottom. This tube is open at both ends. There is another open tube S T, which is soldered into the top of the under vessel and the bottom of the upper vessel, and reaches almost to its top. These two tubes serve also to support the upper vessel. A third tube G F is soldered into the top of the upper vessel, and reaches almost to its bottom. This tube is open at both ends, but the orifice G is very small. Now suppose the uppermost vessel filled with water to the height E N, E *e* being its surface a little below T. Stop the orifice G with the finger, and pour in water at A. This will descend through A B, and compress the air in O P Q R into less room. Suppose the water in the under vessel to have acquired the surface C *c*, the air which formerly occupied the whole of the spaces O P Q R and K L *e* E will now be contained in the spaces *o* P *c* C and K L *e* E; and its elasticity will be in equilibrio with the weight of the column of water whose base is the surface E *e*, and whose height is A *c*. As this pressure is exerted in every part of the air, it will be exerted on the surface E *e* of the water of the upper vessel; and if the pipe F G were continued upwards, the water would be supported in it to a height *e* H above E *e*, equal to A *c*. Therefore, if the finger be now taken from off the orifice G, the fluid will spout up through it to the same height as if it had fallen through a tube whose altitude is *e* H. So long as there is any water in the vessel K L M N there will be a discharge through the orifice: therefore the play of the fountain will continue whilst the water contained in the upper vessel, having spouted out, falls down through the pipe A B; the height of the water measured from the basin V A W to the surface of the water in the lower vessel O P Q R is always equal to the height measured from the top of the jet to the surface of the water in the vessel K L M N. Now, since the surface E *e* is always falling, and the water in the lower vessel always rising, the height of the jet must continually decrease, till it is shorter by the depth of K L M N, which is empty, added to the depth of O P Q R, which is always filling; and when the jet is fallen so low, it immediately ceases to play.

7. A machine designed to raise water to a great height for the irrigation of land, in such situations as have the advantage of a small fall, is described in Dr Darwin's *Phytologia:* as it depends on the principle of Hiero's fountain, it may properly be inserted here.

Fig. 211, *a*, *b*, is the stream of water.
b, *c*, *c*, represents the water-fall, supposed to be 10 feet.

d, e, are two leaden or iron vessels, containing a certain quantity of water, which may be computed to be about four gallons each.

f, g, h, i, k, l, are leaden vessels, each holding about two quarts.

o, p, two cocks, each of which passes through two pipes, opening the one and closing the other.

q, r, is a *water-balance,* that moves on its centre *s,* and by which the two cocks *o* and *p* are alternately turned.

t, u, and *w, x,* are two air-pipes of lead, both internally 1¼ inch in diameter.

y, z; y, z; y, z; are water-pipes, each being one inch in diameter.

The pipe *b, e, c,* is always full from the stream *a, b:* the small cisterns *g, i, l,* and the large one *d,* are supposed to have been previously filled with water. The fluid may then be admitted by turning the cock *o,* through the pipe *c, e,* into the large cistern *e.* This water will press the air confined in the cistern *e* up the air-pipe *w, x,* and will force the fluid out of the cisterns *g, i, l,* into those marked *h, k,* and C.—At the same time, by opening B, the water and condensed air, which previously existed in the large cistern *d,* and in the smaller ones marked *f, h, k,* will be discharged at B. After a short time, the water-balance, *q, r, s,* will turn the cocks, and exclude the water, while it opens the opposite ones: the cisterns *f, h, k,* are emptied in their turns by the condensed air from the cistern *d,* as the water progressively enters the latter from the pipe *b, c.*

8. A very ingenious application of the same principle has been made in the celebrated Hungarian machine, at Chemnitz. The best account we have been able to obtain of this is the following:

In fig. 213, A represents the source of water elevated 136 feet above the mouth of the pit. From this there runs down a pipe D of four inches diameter, which enters the top of a copper cylinder B, 8½ feet high, 5 feet diameter, and 2 inches thick, and reaches to within 4 inches of the bottom: it has a cock at I.

This cylinder has a cock at Q, and a very large one at N. From its top proceeds a pipe V E C, two inches in diameter, which goes 96 feet down the pit, and is inserted into the top of another brass cylinder C, which is 6½ feet high, four feet diameter, and two inches thick: the latter containing about 83 cubic feet, which is nearly one-half of the capacity of the former, viz. 170 cubic feet. There is another pipe F O of four inches diameter, which rises from within four inches of the bottom of this lower cylinder, is soldered into its top, and rises to the trough Z which carries off the water from the mouth of the pit. This lower cylinder communicates at the bottom with the water O, which collects in the drains of the mines. A large cock P serves to exclude or admit this water; another cock M at the top of this cylinder communicates with the external air.

Now, suppose the cock I shut, and all the rest open: the upper cylinder will contain air, and the lower cylinder will be filled with water, because it is sunk so deep that its top is below the usual surface of the mine-waters. Shut the cocks Q, N, M, P, and open the cock I. The water of the source A must run in by the orifice J, and rise in the upper cylinder, compressing the air above it and along the pipe V E C, and thus acting on the surface of the water in the lower cylinder. It will therefore cause it to rise gradually in the pipe O F, where it will always be of such a height that its weight balances the elasticity of the compressed air. Suppose no issue given to the air from the upper cylinder, it would be compressed into one-fifth of its bulk by the column of 136 feet high; for a column of 34 feet nearly balances the ordinary elasticity of the air. Therefore, when there is an issue given to it through the pipe V E C, it will drive the compressed air along this pipe, and it will expel water from the lower cylinder. When the upper cylinder is full of water, there will be 34 cubic feet of water expelled from the lower cylinder. If the pipe O P had been more than 136 feet long, the water would have risen 136 feet, being then in equilibrio with the water in the feeding pipe D by the intervention of the elastic air; but no more water would have been expelled from the lower cylinder than what fills this pipe. But the pipe being only 96 feet high, the water will be thrown out at Z with a considerable velocity. If it were not for the great obstructions which water and air must meet with in their passsage along pipes, it would issue at Z with a velocity of more than 50 feet per second. It issues however much more slowly, and at last the upper cylinder is full of water, and the water would enter the pipe V E and enter the lower cylinder, and, without displacing the air in it, would rise through the discharging pipe O P, and run off to waste. To prevent this there hangs in the pipe V E a cork ball or double cone, by a brass wire which is guided by holes in two cross pieces in that pipe. When the upper cylinder is filled with water, this cork plugs up the orifice V, and no water is wasted; the influx at J now stops. But the lower cylinder contains compressed air, which would balance water in a discharging pipe 136 feet high, whereas O P is only 96. Therefore the water will continue to flow at Z till the air has so far expanded as to balance only 96 feet of water, that is, till it occupies one-half of its ordinary bulk, that is, one-fourth of the capacity of the upper cylinder, or 42½ cubic feet. Therefore 42½ cubic feet will be expelled, and the efflux at Z will cease; and the lower cylinder is about one-half full of water. When the attending workman observes this, he shuts the cock I. He might have done this before, had he known when the orifice V was stopped; but no loss ensues from the delay. At the same time the attendant opens the cock N the water issues with great violence, being pressed by the condensed air from the lower cylinder. It therefore issues with the sum of its own weight and of this compression. These gradually decrease together, by the efflux of the water and the expansion of the air; but this efflux stops before all the water has flowed out; for there is 42½ feet of the lower cylinder occupied by air. This quantity of water remains, therefore, in the upper cylinder nearly: the workman knows this, because the discharged water is received first of all into a vessel containing three-fourths of the capacity of the upper cylinder. Whenever this is filled, the attendant opens the cock P by a long rod which goes down the shaft; this allows the water of the mine to fill the lower cylinder, and the air to get into the upper cylinder, which permits the remaining water to run out of it. Thus every thing is brought into its first condition; and when the attendant sees no more water come out at N, he shuts the cocks N and M, and opens the cock I, and the operation is repeated.

There is a very surprising appearance in the working of this engine. When the efflux at Z has stopped, if the cock Q be opened, the water and air rush out together with prodigious violence, and the drops of water are changed into hail or lumps of ice. It is a sight usually shown to strangers, who are desired to hold their hats to receive the blasts of air; the ice comes out with such violence as frequently to pierce the hat like a pistol bullet. This rapid congelation is a remarkable instance of the general fact, that air by suddenly expanding generates cold, its capacity for heat being increased.

The above account of the procedure in working this engine shows that the efflux both at Z and N becomes very slow near the end. It is found convenient therefore not to wait for the complete discharges, but to turn the cocks when about 30 cubic feet of water have been discharged at Z: more work is done in this way. A gentleman of great accuracy and knowledge of these subjects took the trouble of noticing particularly the performance of the machine. He observed that each stroke, as it may be called, took up about three minutes and one-eighth; and that 32 cubic feet of water were discharged at Z, and 66 were expended at N. The expense therefore is 66 feet of water falling 136 feet, and the performance is 32 raised 96, and they are in the proportion of 66 × 136 to 32 × 96, or of 1 to 0,3422, or nearly as 3 to 1. This is superior to the performance of the most perfect undershot mill, even when all friction and irregular obstructions are neglected; and is not much inferior to any overshot pump-mill that has yet been erected. When we reflect on the great obstructions which water meets with in its passage through long pipes, we may be assured, that, by doubling the size of the feeder and discharger, the performance of the machine will be greatly improved; we do not hesitate to say, that it would be increased one-third: it is true that it will expend more water; but this will not be nearly in the same proportion, for most of the deficiency of the machine arises from the needless velocity of the first efflux at Z. The discharging pipe ought to be 110 feet high, and not give sensibly less water. Then it must be considered how inferior in original expense this simple machine must be to a mill of any kind which would raise 10 cubic feet 96 feet high in a minute; and how small the repairs on it need be, when compared with a mill. And, lastly, let it be noticed, that such a machine can be used where no mill whatever can be put in motion. A small stream of water, which would not move any kind of wheel, will here raise one-third of its own quantity to the same height, working as fast as it is supplied.

For these reasons, the Hungarian machine eminently deserves the attention of mathematicians and engineers, to bring it to its utmost perfection, and into general use. There are situations where this kind of machine may be very useful. Thus, where the tide rises 17 feet, it may be used for compressing air to seven-eighths of its bulk; and a pipe leading from a very large vessel inverted in it may be used for raising the water from a vessel of one-eighth of its capacity 17 feet high; or if this vessel has only one-tenth of the capacity of the large one set in the tide-way, two pipes may be led from it, one into the small vessel, and the other into an equal vessel 16 feet higher, which receives the water from the first. Thus one-sixteenth of the water may be raised 34 feet, and a smaller quantity to a still greater height; and this with a kind of power that can hardly be applied any other way. Machines of this kind are described by Schottus, Sturmius, Leupold, and other old writers; and they should not be forgotten, because opportunities may offer of making them highly beneficial.

9. Mr John Whitley Boswell has devised an apparatus which when attached to such a machine as that at Chemnitz will enable it to work itself without attendance. The de-

scription of this will be presented to the reader in Mr Boswell's own words.

Fig. 213. A is the reservoir, or upper level of water.

B, a chamber made of sufficient strength to bear the internal pressure of a column of water the height of A above it, multiplied by its own base.

C, a chamber of the same strength as B, but of a smaller size; it is placed at the bottom of the pit from which the water is to be raised, and under the level of the water.

These chambers would be stronger with the same materials, if of a globular or cylindrical form; but the square shape is used in the drawing merely for the facility of representing the position of the parts.

D, a pipe from the reservoir A which passes through the top of B and ends near its bottom, to convey water from A to B.

E, a pipe from the top of B to the top of C, to convey air from B to C.

F, a pipe from the bottom of C to the level of the ground at the top of the pit, to carry off the water from the pit.

G, a pipe from the bottom of B to carry off the water from it.

H, a vessel to contain the water used in working the cocks; it is only placed on the top of B to save the construction of a stand on purpose for it.

I, a cock, or movable valve, (worked by the lever there represented,) in the large pipe D.

K, a stop-cock in the small pipe which conveys water from D to H. Its use is to make the engine work faster or slower, by letting water more or less quick into H; or to stop it altogether from working when required.

L, a movable valve, or cock in the small pipe L K. The lever which works it is connected by a strong wire with the lever which works I, and is balanced by a weight at its opposite extremity, sufficient to open both these cocks and shut N, when not prevented by a counter weight.

N, a cock in the pipe G to open and shut it as wanted.

O, a self-moving valve in the pipe F, which permits the water to pass upwards, but prevents its return.

P, a self-moving valve at the bottom of C, which permits the water to pass into C, but prevents any from passing out of it; it is furnished with a grating, to prevent dirt getting in.

R, a vessel suspended from the levers of I and L, capable of containing a weight of water sufficient to shut them.

S, a vessel suspended from the lever of N: it must contain water enough by its weight to open N: it is connected by a chain to R, to keep it down as long as N is open.

T, a syphon passing from the bottom of H, near its upper edge, and down again to the mouth of R.

V, a self-moving valve of a sufficient levity to rise, when the water in B comes up to it, and close the pipe E; into which no water would else pass from B. A ball-cock, such as used in common water cisterns, would do here.

X, a syphon from the bottom of R rising within an inch of its top, and passing down again to the mouth of S.

Y, a small pipe at the bottom of S; this may have a stop-cock to regulate it, which, when stopped, will also stop the engine.

The mode of this engine's working is as follows: suppose the vessels V, H, R, and S empty of water, and the cocks K and Y open, and the vessel C full of water. The weight on the lever of L will then open the cocks L and I, on which the water from A will flow into B and H. As the water rises in B, it will force the air through E into C, which strongly pressing on the water in C, will force it up through the pipe F, till the water in B rises to the level of V and closes it, at which time H will be full of water (the quantity flowing in being so regulated by the cock K,) and the water will flow from it though the syphon T into the vessel R, which as it fills shuts the cock I and L and prevents any more water coming into B and H. When R is full, the water flows through its syphon X, which fills S, and by it opens N, which empties B of water, and keeps N open as long as there is any water in H.

When H is empty, B will be so too, (being so regulated by the cock K,) on which, in a moment or two, R and S will also be empty, which will cause the cocks I and L to open, and all things will be again in the state first supposed, for a repetition of the operations described.

To stop the engine, the cocks at K and Y should be shut, while S is full of water. To set it working, they should be open; and this is all the attendance it will require. As no one but an engineer should attempt to construct such an engine as this, it was useless to represent the manner of connecting the pipes by flaches or otherwise, or the proper methods of fastening and closing the parts, which are well known to such as have made this art their study.

In No. 5, of the New Series of Nicholson's Journal, Mr Boswell has made some further improvements in the application of the Hungarian machine.

10. The *spiral pump* is a very curious hydraulic engine, which operates on nearly the same principle as the Hungarian machine. The first engine of this kind, of which we have seen any account, was invented and erected by H. Andreas Wirtz, a tinplate-worker of Zurich, at a dye-house in Limmat, in the vicinity of that city. It consists of a hollow cylinder, like a very large grindstone, turning on a horizontal axis, and partly plunged in a cistern of water. The axis is hollow at one end, and communicates with a vertical pipe. This cylinder or drum is formed into a spiral canal, by a plate coiled up within it like the main spring of a watch in its box; only the spires at a distance from each other, so as to form a conduit for the water of uniform width. This spiral partition is well joined to the two ends of the cylinder, and no water escapes between them. The outermost turn of the spiral begins to widen about three-fourths of a circumference from the end, and this gradual enlargement continues nearly a semicircle, this part being called the horn: it then widens suddenly, forming a scoop or shovel. The cylinder is so supported that this shovel may, in the course of rotation, dip several inches into the water. As the cylinder turns upon its axis, the scoop dips and takes up a certain quantity of water before it emerges again. This quantity is sufficient to fill the horn; and this again is nearly equal in capacity to the outermost uniform spiral round.

After the scoop is emerged, the water passes along the spiral by the motion of it round the axis, and drives the air before it into the rising pipe, where it escapes. In the mean time air comes into the mouth of the scoop; and when the scoop again dips into the water, it again takes in some of that fluid. Thus there becomes a part filled with water, and a part filled with air. Continuing this motion, a second round of water will be received, and another of air. The water in any turn of the spiral will have its two ends on a level; and the air between the successive columns of water will be in its natural state; for since the passage into the rising pipe or main is open, there is nothing to force the water and air into any other position. But since the spires gradually diminish in their length, it is plain that the column of water will gradually occupy more and more the circumference of each. At last it will occupy a complete turn of some spire that is near the centre; and when sent further in by the continuance of the motion, some of it will run back over the top of the succeeding spire. Thus it will run over into the right-hand side of the third spire, and consequently will push the water of this spire backwards, and raise its other end, so that *it* will likewise run over backwards *before* the next rotation be completed. At length this change of disposition will reach the outermost spire, and some water will run over into the horn and scoop, and finally into the cistern.

But as soon as water gets into the rising pipe, and rises a little into it, it stops the escape of the air when the next scoop of water is taken in. Hence there are then two columns of water acting against each other by hydrostatic pressure, and the intervening column of air: they must compress the air between them, and the water and air columns will now be unequal: this will have a general tendency to keep the whole water back, and cause it to be higher on the left or rising side of each spire than on the right or descending side: the excess of height being just such as produces the compression of the air between that and the preceding column of water. This will go on increasing as the water mounts in the rising pipe; for the air next to the rising pipe is compressed at its inner end with the weight of the whole column in the main: and it must be as much compressed at its outer end, which must be done by the water column without it; and this column exerts this pressure partly by reason that *its* outer end is higher than its inner end, and partly by the transmission of the pressure on its outer end by air, which is similarly compressed from without. Thus it will happen that each column of water being higher at its outer than at its inner end, compresses the air on the water column beyond or within it, which transmits this pressure to the air beyond *it*, adding to it the pressure arising from its own want of level at the ends. Consequently, the greatest compression, viz. that of the air next the main, is produced by *the sum of all the transmitted pressures;* and these are the sum of all the differences between the elevations of the inner ends of the water columns above their outer ends: and the height to which the water will rise in the main will be just equal to this sum.

Suppose the left-hand spaces of each spire to be filled with water, and the right-hand spaces filled with air, as is shown, in regard to one spire, in fig. 214. There is a certain gradation of compression which will keep things in this position: for the spaces manifestly decrease in arithmetical progression; and so do the hydrostatic heights and pressures: if, therefore, the air be dense in the same progression all will be in hydrostatical equilibrium. Now this may obviously be produced by the mere motion of the machine; for since the density and compression in each air column is supposed inversely as the magnitude of the column, the quantity of air is the same in all; therefore the column first taken in will pass gradually inwards, and the increasing compression will cause it to occupy precisely the whole right-hand of every spire. The gradual diminution of the water columns will be produced, during the motion, by the water running over backwards at the top from spire to spire, and ultimately coming out by the scoop. Since the hydrostatic height of each water column is now the greatest possible, viz. the diameter of the spire, it is evident that this disposition of the air and water will raise the water to the greatest height. This disposition may be obtained thus: let C B be a vertical radius of the wheel, C being the centre, and B the highest point [the figure may easily be drawn] upon C B, take C L to C B, as the density of the external air to its density in the last column next the rising pipe or main; that is, make C L to C B as 34 feet, (the height of the column of water which balances the pressure of the atmosphere,) to the sum of 34 feet, and the height of the rising pipe: then divide B L into such a number of turns that the sum of their equal diameters shall be equal to the height of the main; lastly, bring a pipe straight from L to the centre C. Such is the construction of the spiral pump, as originally invented by Wirtz: it certainly indicates very considerable mechanical knowledge and sagacity.

But when the main is very high this construction will require either an enormous diameter of the drum, or many turns of a very narrow pipe. In such cases it will be much better to make the spiral in the form of a cork-screw, than of this flat form like a watch-spring. The pipe which forms the spiral may be wrapped round the frustrum of a cone, whose greatest diameter is to the least, (which is next to the rising pipe,) in the proportion just assigned to C B and C L. By this construction the water will so stand in every round as to have its upper and lower surfaces tangents to the top and bottom of the spiral, and the water columns will occupy the whole ascending side of the machine while the air occupies the descending side. This form is far preferable to the flat form: it will allow us to employ many turns of a large pipe, and therefore produce a great elevation of a large quantity of water.

The same thing will be still better accomplished by wrapping the pipe on a cylinder, and making it gradually tapering to the end, in such a manner that the contents of each spire may be the same as when it is wrapped round the cone. It will raise the water to a greater height, (though certainly with an increase of the impelling power,) by the same number of spires, because the vertical or pressing height of each column is greater.

In the preceding description of this machine, that construction has been chosen which made its principle and manner of working most evident, namely, that which contained the same material quantity of air in each turn of the spiral, more and more compressed as it approaches to the rising pipe. But this is not the best construction: for we see that in order to raise water to the height of a column of 34 feet, the air in the last spire is compressed into half its space; and the quantity of water delivered into the main at each turn is but half what was received into the first spire, the rest flowing back from spire to spire, and being discharged at the spout.

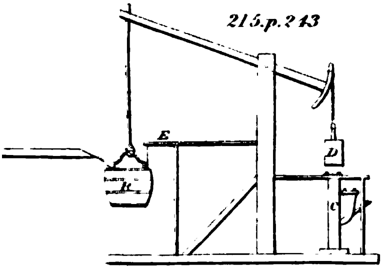
But the construction may be such that the quantity of water in each spire may be the same that was received into the first; by which means a greater quantity, (double in the instance now given,) will be delivered into the main, and raised to the same altitude by very nearly the same force. This may be done by another proportion of the capacity of the spires; either by a change of their calibre, or of the diameters of the solid on which they are folded. Suppose the bore to be uniform throughout, the diameters must so vary that the constant column of water and the column of air, compressed to the proper degree, may occupy the whole circumference. Let A be the column of water which balances the pressure, and H the height to which the water is to be raised. Let A be to $A + H$ as 1 to m. Then it is plain that m will represent the density of the air in the last spire, if its natural density be 1, because it is pressed by the column $A + H$ while the common air is pressed by A. Let 1 represent the constant water column, and consequently it will be nearly equal to the air column in the first spire: then the whole circumference of the last spire must be $1 + \frac{1}{m}$, in order to hold the water 1, and to compress the air into the space $\frac{1}{m}$ or $\frac{A}{A+H}$. The circumference of the first spire is $1 + 1$ or 2: and if D and d be the diameters of the first and last spires, we have $2 : 1 + \frac{1}{m} :: D : d$, or $2m : m + 1 :: D : d$. If, therefore, a pipe of uniform bore be wrapped round a conic frustrum, of which D and d are the end diameters, the spirals will be very nearly such as will answer the purpose. It will not be *quite* exact, for the intermediate spirals will be rather too large: the conoidal frustrum should in strictness be formed by the revolution of a logarithmic curve. With such a spiral the full quantity of water which was confined in the first spire will find room in the last, and will be sent into the main at every rotation. This is a very great advantage, especially when the water is to be much raised. The saving of power by this change of construction is always proportional to the greatest compression of the air.

The chief difficulty in any of these forms is in determining the form and position of the horn and the scoop; yet on this the performance of the machine greatly depends. The following instructions will render this tolerably easy. Let A B E O, (fig. 214,) represent the first or outermost spire, of which the axis is C. Suppose the machine immerged up to the axis in the water whose surface is V V′: it has been seen that it is most effective when the surfaces K B and O n of the water columns are distant from each

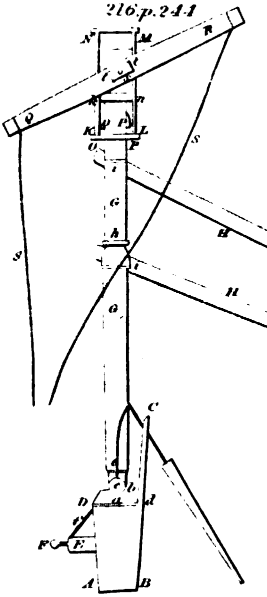
HYDRAULIC ENGINES

From 214 to 220

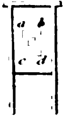
215. p. 243



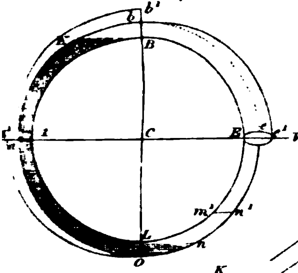
216. p. 244



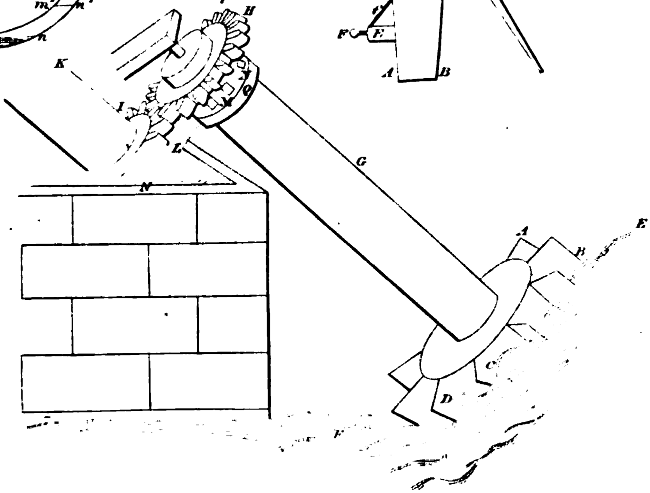
217. p. 244



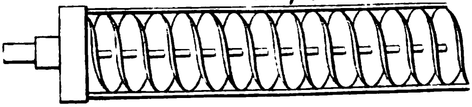
214. p. 240



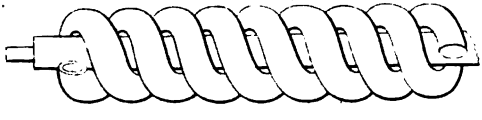
218. p. 246



219. p. 246



220. p. 246



11. Desaguliers describes, in the second volume of his *Experimental Philosophy*, a very simple contrivance to raise water, which is this: to one end of a rope is fixed a large bucket, having a valve at its bottom, opening upwards; to the other end is fastened a square frame, and the cord is made to pass over two pulleys, each of about 15 inches diameter, (and fixed in a horizontal plane,) in such a manner that as the bucket descends the frame ascends with equal velocity, and *vice versâ*. The frame is made to run freely upon four vertical iron guide-rods passing through holes at its four corners; and when the bucket is filling with water at the well, the frame stands at the horizontal plane to which the water is to be raised; when the bucket is full a man steps upon the frame; (his weight, together with that of the frame, exceeding the weight of the vessel and its contained water;) this gives an ascending motion to the bucket, and causes the valve in its bottom to close. When the bucket is raised to the proper height, a hook fixed there catches into a hasp at the side of the bucket, turns it over, and causes it to empty its water into a trough which conveys it where it is required: at this time the man and the descending frame have arrived at a platform which prevents their further descent, where the man remains, till he finds the bucket above is empty; when he steps from the frame, and runs up a flight of stairs to the place from which he descended: the bucket, in the mean while, being somewhat heavier than the frame, descends to the water, and raises the frame to its original position. Thus the work is continued, the man being at rest during his descent, and labouring in the ascent.

Desaguliers employed in this kind of work a "*tavern drawer*," who weighed 160 lbs. whom he desired to go up and down forty steps of 6½ inches each, (in all about 22 feet,) at the same rate he would go up and down all day. He went up and down twice in a minute; so that, allowing the bucket with a quarter of a hogshead in it to weigh 140 lbs. he is able to raise it up through 22 feet twice in a minute: this Desaguliers estimates as equivalent to a whole hogshead raised 11 feet in a minute, and rather exceeds what he has assigned as a maximum of human exertion.

This machine is in many cases not only the most simple, but the *best* that can be devised; yet it is one that, without due precautions, is likely to be a very bad one. The frame on which the man steps must be brought up to its place again by a preponderancy in the machine when unloaded; it should arrive precisely at the same time with the man; but it may arrive sooner or later. If sooner, it is of no use, and wastes power in raising a counterpoise which is needlessly heavy, or in fact less water is elevated than the man is able to elevate; if later there is a loss of time. Hence the perfection of this truly simple machine requires the judicious combination of two maximums, each of which varies in a ratio compounded of two other ratios. In will not be difficult, however, to adjust the proportions of the weight of the bucket and that of the frame: for if B denote the weight of the bucket, F that of the frame, and ϕ the force necessary to overcome the friction and the inertia of the pulleys, g denoting 32 1-6th feet, t the time occupied in walking up the steps, and s the space ascended or descended, then must B and F be so adjusted as to satisfy the following equation, viz.

$$s = \frac{B - F}{B + F + \phi} \cdot \tfrac{1}{2} g t^2$$

If there be a spring affording but a small quantity of water, or having but a small fall, it is possible by the loss of some of the water to raise the rest to supply a gentleman's seat, or any place where it is wanted; but in a less quantity than what runs waste, if the place to which the water is to be raised is higher than the spring or reservoir from which the water falls. Schottus long ago contrived an engine for this purpose: but the first who put such a thing into execution was Gironimo Finugio, at Rome, in 1616; and the first in this country was George Gerves, a carpenter, who, in the year 1725, erected an engine called the Multiplying wheel Bucket-engine, at the seat of Sir John Chester, at Chichley, in Buckinghamshire. This engine was much approved by Sir Isaac Newton, Dr Desaguliers, and Mr Beighton, and was certainly very ingenious. The water from a spring descended in a large bucket hanging by a cord from an axle, while a smaller quantity was raised from the same place by a cord hanging from a wheel on the same axle: a fly and other regulating apparatus were added to make the engine work itself, which it did for many years without being out of order. As a whole, however, the contrivance is complex; and we are not aware that any other engines of the same kind have been erected. A description, with a plate, may be seen in Desagulier's second volume.

12. Mr H. Sarjeant, of Whitehaven, contrived a very cheap engine for raising water, for which the Society for the Encouragement of Arts awarded him a silver medal in the year 1801. A sketch of this simple invention is given in fig. 215.

This engine was erected at Irton-hall, which is situated on an ascent of 60 or 61 feet perpendicular height: at the foot of this elevation, about 140 yards distant from the offices, there runs a small stream of water; and, in order to procure a constant supply of that necessary fluid, the object was to raise such stream to the house for culinary or domestic uses. With this view, a dam was formed at a short distance above the current, so as to cause a fall of about four feet: the water was then conducted through a wooden trough, into which a piece of leaden pipe, two inches in diameter, was inserted, and part of which is delineated at A.

The stream of this pipe is directed in such a manner as to run into the bucket B, when the latter is elevated; but, as soon as it begins to descend, the stream passes over it, and flows progressively to supply the wooden trough or well, at the foot of which stands the forcing-pump C, being three inches in diameter.

D is an iron cylinder attached to the pump-rod, which passes through it: such cylinder is filled with lead, and weighs about 240 pounds. This power works the pump, and forces the water to ascend to the house through a pipe one inch in diameter, and which is 420 feet in length.

At E is fixed a cord, which, when the bucket approaches to within four or five inches of its lowest projection, extends, and opens a valve in the bottom of the vessel through which the water is discharged.

An engine in a great degree similar to this was erected some years ago by the late James Spedding, Esq. for a lead mine near Keswick, with the addition of a smaller bucket which emptied itself into the larger near the beginning of its descent, without which addition it was found that the beam only acquired a libratory motion, without making a full and effective stroke.

To answer this purpose in a more simple way, Mr Sarjeant constructed the small engine in such a manner as to finish its stroke, (speaking of the bucket end,) when the beam comes into a horizontal position, or a little below it. By this means the lever is virtually lengthened in its descent in the proportion of the radius to the cosine, of about thirty degrees, or as seven to six nearly, and consequently its power is increased in an equal proportion.

It is evident that the opening of the valve might have been effected, perhaps better, by a projecting pin at the bottom; but Mr S. chose to give an exact description of the engine as it stands. It has now been some years in use, and completely answers the purpose intended.

The only artificers employed, except the plumber, were a country blacksmith and carpenter; and the whole cost, exclusive of the pump and pipes, did not amount to 5*l.*

In a letter, dated Whitehaven, April 28, 1801, Mr Sarjeant observes, that the pump requires about 18 gallons of water in the bucket to raise the counter-weight, and make a fresh stroke in the pump; but it makes three strokes in a minute, and gives about a half-gallon into the cistern at each stroke. He adds, "I speak of what it did in the driest part of last summer; when it supplied a large family, together with work-people, &c. with water for all purposes, in a situation where none was to be had before, except some bad water from a common pump, which has been since removed. But the above supply being more than sufficient, the machine is occasionally stopped to prevent wear, which is done by merely casting off the string of the bucket-valve."

13. Mr Benjamin Dearborn has contrived an hydraulic engine which may be conveniently added to a common pump, and thereby renders it useful in further elevating water, and particularly in extinguishing fires: the following description of his apparatus is extracted from the *Memoirs of the American Academy.*

Fig. 216. A, B, C, D, represents a pump, the form of which is similar to that of the pumps commonly employed on ship-board.

E, the spout.

F, a stopper.

D, *d*, a plank-cap, that is fitted to the pump, and provided with leather on its lower surface, being secured by the screws *a*, *b*: in the centre is a hole, through which the spear of the pump passes, and round which a leather collar is made, as represented at the letter *c.*

g, a nut for the screw *b*.

f, a square piece of wood that is nailed across one end of the plank-cap, through both which the screw *a* is introduced: a hole is made through such piece and the cap that communicates with the bore of the pump.

G, G, a wooden tube, which may be of any requisite length, and consist of any number of joints; it is made square at the lower extremity, and perforated for the reception of the cock; the upper end being made with a *nice* shoulder.

e, a wooden cock that opens or shuts the communication between the pump and the tube, being furnished on the opposite side with a handle and with a lock, in case it should be found necessary.

h, *h*, are two ferules, the object of which is to prevent the tube from splitting.

H, H, braces, each of which ought to be crossed over another, as nearly at right angles as possible.

i, *i*, are irons in form of a staple, which surround the tube, and pass through the braces; their ends being perforated with holes for fore-locks.

K, L, M, N, is a head made of five pieces of wood; *k*, *l*, *m*, *n*, a square piece, in the lower part of which is a hole for the reception of the extremity of the tube, and which piece rests on the shoulder *o*, *p*; to the lower end of this head is nailed a piece of leather, with a hole in its centre, similar to that made in the wood. Another piece of leather of the same form is placed on the top of the tube, and between both is a circle of thin plate-brass; the two pieces of leather and the brass being pressed between the lower end of the head and the shoulder of the tube. Their edges are delineated at *o*, *p*.

K, N, and L, M, are the edges of two pieces of plank, of a similar width with the head, to which they are closely nailed, each being provided with a tenon, that passes through a mortice in the end of the piece O, P: both tenons have holes for a fore-lock at *q*.

O, P, a piece of plank of the same width as the sides; the centre of which is perforated, in order that the tube may pass through; and in each end of which is a mortice for the reception of the tenons.

N, M, a cap.

r, *r*, are two pieces nailed to the side of the tube; the lower extremity of each is provided with a truck, with a view to lessen the friction of the head in its horizontal revolution.

q, *q*, represents fore-locks, the design of which is to fasten down the head, and prevent the water from escaping at the joint *o*, *p*.

Q, R, is a wooden conductor: the extremity marked with the letter Q being solid, while the opposite end, R, is bored with a small auger.

s, a bolt that passes through the conductor and head, and being secured on the back with a fore-lock or nut: this bolt is rounded near the head, and square in the middle.

t, *u*, *w*, *x*, represents a piece of iron or brass, designed to prevent the head of the bolt from wearing into the wood.

S, S, are ropes for the direction of the conductor.

Fig. 217 represents the head without such conductor.

a, *b*, *c*, *d*, is a thick brass plate, the centre of which is perforated, so as to admit a passage to impurities, that might otherwise obstruct the conductor: for which purpose a piece of leather is nailed under it to the head. The square hole in the centre is adapted to the size of the bolt, which it prevents from turning. The conductor has a hollow cut round the bolt on the inside, of the same size as the circle of holes in the brass; round such cavity is nailed, on the face of the conductor, a piece of leather, that plays on the margin of the brass plate when the conductor is in motion.

In the conclusion of his memoir, Mr Dearborn observes, that he has raised a tube of 30 feet on his pump; and, though the severity of the season had prevented him from completing it, so that one person only could work at the brake, yet he is enabled to throw water on a contiguous building, the nearest part of which is 37 feet from the pump, and between 30 and 40 feet in height.

14. *Archimedes's Screw*, or the Spiral Pump, or, as it is

called in Germany, the Water-snail, is a machine for the raising of water, first invented by Archimedes.

Its structure and use will be understood by the following description of it.

Fig. 218. A, B, C, D, is a wheel, which is turned round, according to the order of the letters, by the fall of water E F, which need not be more than three feet. The axle G of the wheel is elevated so as to make an angle of about 44°, or between 45° and 60°, with the horizon; and on the top of that axle is a wheel H, which turns such another wheel I of the same number of teeth; the axle K of this last wheel being parallel to the axle G of the two former wheels. The axle G is cut into a double-threaded screw, fig. 219, exactly resembling the screw on the axis of the fly of a common jack, which must be what is called a right-handed screw, like the wood screws, if the first wheel turns in the direction A B C D; but it must be a left-handed screw, if the stream turns the wheel the contrary way; and the screw on the axle G must be cut in a contrary way to that on the axle K, because these axles turn in contrary directions.

These screws must be covered close over with boards, like those of a cylindrical cask; and then they will be spiral tubes. Or they may be made of tubes of stiff leather, and wrapped round the axles in shallow grooves cut therein, as fig. 220. The lower end of the axle G turns constantly in the stream that turns the wheel, and the lower ends of the spiral tubes are open unto the water. So that, as the wheel and axle are turned round, the water rises in the spiral tubes, and runs out at Q, through the holes M N, as they come about below the axle. These holes, of which there may be any number, as four or six, in a broad close ring on the top of the axle, into which ring the water is delivered from the upper open ends of the screw tubes, and falls into the open box N. The lower end of the axle K turns on a gudgeon, in the water N; and the spiral tubes in that axle take up the water from N, and deliver it into another such a box under the top of K; on which there may be such another wheel as I, to turn a third axle by such a wheel upon it. And in this manner water may be raised to any given height, where there is a stream sufficient for that purpose to act on the broad float-boards of the first wheel.

15. Another kind of engine, called the *Pressure Engine*, several of which have been lately erected in different parts of the country, is used for raising water by the pressure and descent of a column enclosed in a pipe. The principle was first adopted in France, in some machinery erected about 1731, and is described by Belidor, in his *Arch. Hydraul.* lib. iv. ch. 1. But the engine we are now going to describe is the invention of Mr Trevitheck, who probably was not aware that one of a similar nature had been before attempted. It was erected about thirty years ago at the Druid Copper-mine, in the parish of Illogan, near Truro.

A section of it is given in fig. 221.

A B represent a pipe six inches in diameter, through which water descends from the head to the place of its delivery to run off by an adit at S, through a fall of 34 fathoms in the whole; that is to say, in a close pipe down the slope of a hill 200 fathoms long, with 26 fathoms fall, then perpendicularly six fathome till it arrives at B, and thence through the engine from B to S two fathoms. At the turn B the water enters into a chamber C, the lower part of which terminates in two brass cylinders, four inches in diameter, in which two plugs or pistons of lead, D and E, are capable of moving up and down by their piston-rods, which pass through a close packing above, and are attached to the extremities of a chain leading over and properly attached to the wheel Q, so that it cannot slip.

The leaden pipes D and E are cast in their places, and have no packing whatever. They move very easily; and if at any time they should become loose, they may be spread out by a few blows with a proper instrument, without taking them out of their place. On the sides of the two brass cylinders in which D and E move, there are square holes communicating towards F and G, which is a horizontal trunk or square pipe, four inches wide and three inches deep. All the other pipes G, G, and R, are six inches in diameter, except the principal cylinder wherein the piston H moves; and this cylinder is ten inches in diameter, and admits a nine-foot stroke, though it is here delineated as if the stroke were only a three-foot.

The piston-rod works through a stuffing-box above, and is attached to M N, which is the pit-rod, or a perpendicular piece divided into two, so as to allow its alternate motion up and down, and leave a space between, without touching the fixed apparatus or great cylinder. The pit-rod is prolonged down into the mine, where it is employed to work the pumps; or if the engine were applied to mill-work, or any other use, this rod would form the communication of the first mover.

K L is a tumbler, or tumbling-bob, capable of being moved on the gudgeon V, from its present position to another, in which the weight L shall hang over the same inclination on the opposite side of the perpendicular, and consequently the end K will then be as much elevated as it is now depressed.

The pipe R S has its lower end immersed in a cistern, by which means it delivers its water without the possibility of the external air introducing itself; so that it constitutes a torricellian column, or water barometer, and renders the whole column from A to S effectual: as we shall see in our view of the operation.

Let us suppose the lower bar K V of the tumbler to be horizontal, and the rod P O so situated, as that the plugs or leaden pistons D and E shall lie opposite to each other, and stop the water ways G and F. In this state of the engine, though each of these pistons is pressed by a force equivalent to more than 1000 pounds, they will remain motionless, because these actions being contrary to each other, they are constantly in equilibrio. The great piston H being here shown as at the bottom of its cylinder, the tumbler is to be thrown by hand into the position here delineated. Its action upon O P, and consequently upon the wheel Q, draws up the plug D, and depresses E, so that the water-way G becomes open from A B, and that of F to the pipe R; the water consequently descends from A to C; thence to G G G, until it acts beneath the piston H. This pressure raises the piston, and if there be any water above the piston, it causes it to rise and pass through F into R. During the rise of the piston, (which carries the pit-rod M N along with it,) a sliding block of wood I, fixed to this rod, is brought into contact with the tail K, of the tumbler, and raises it to the horizontal position, beyond which it oversets by the acquired motion of the wheel L.

The mere rise of the piston, if there were no additional motion in the tumbler, would only bring the two plugs D and E to the position of rest, namely, to close G and F, and then the engine would stop; but the fall of the tumbler carries the plug D downwards quite clear of the hole F, and the other plug E upwards, quite clear of the hole G. These motions require no consumption of power, because the plugs are in equilibrio, as was just observed.

In this new situation the column A B no longer communicates with G, but acts through F upon the upper part of the piston H, and depresses it; while the contents of the great cylinder beneath that piston are driven out through G G G, and pass through the opening at E into R. It may be observed, that the column which acts against the piston is assisted by the pressure of the atmosphere, rendered active by the column of water hanging in R, to which that assisting pressure is equivalent, as has already been noticed.

When the piston has descended through a certain length, the slide or block at T, upon the pit-rod, applies against the tail K of the tumbler, which it depresses, and again oversets; producing once more the position of the plugs D E, here delineated, and the consequent ascent of the great piston H, as before described. The ascent produces its former effect on the tumbler and plugs; and in this manner it is evident that the alterations will go on without limit, or until the manager shall think fit to place the tumbler and plugs D E in the positions of rest; namely, so as to stop the passages F and G.

The length of the stroke may be varied by altering the positions of the pieces T and I, which will shorten the stroke the nearer they are together; as in that case they will sooner alternate upon the tail K.

As the sudden stoppage of the descent of the column A B, at the instant when the two plugs were both in the water-way, might jar and shake the apparatus, those plugs are made half an inch shorter than the depth of the side holes; so that in that case the water can escape directly through both the small cylinders to R. This gives a moment of time for the generation of the contrary motion in the piston and the water in G G G, and greatly deadens the concussion which might else be produced.

Some former attempts to make pressure-engines upon the principle of the steam-engine have failed; because water, not being elastic, could not be made to carry the piston onwards a little, so as completely to shut one set of valves and open another. In the present judicious construction, the tumbler performs the office of the expansive force of steam at the end of the stroke.

Mr Boswell suggests, as a considerable improvement, that the action of this engine should be made elastic by the addition of an air-chamber, on the same principle as that used in fire-engines; this, he thinks, might be best effected by making the piston hollow, with a small orifice in the bottom, and of a larger size, to serve for this purpose, as the spring of the air would then act both on the upward and downward pressure of the water.

There are many other ingenious hydraulic engines of great utility, which the limits of our work will not permit us to describe; in order, therefore, to supply the deficiency, we shall add a catalogue of the most important writings on this kind of engine.

PUMPS

From 221 to 224

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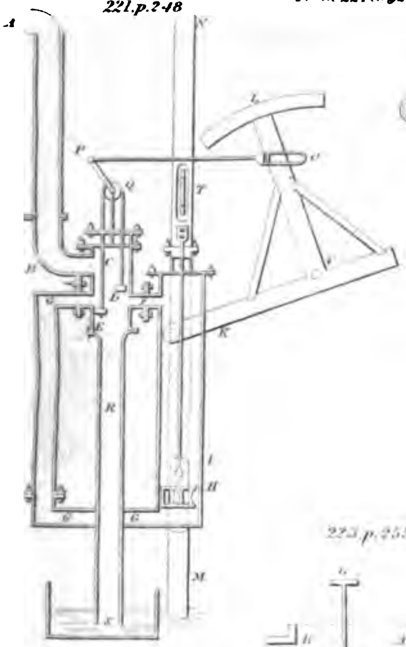

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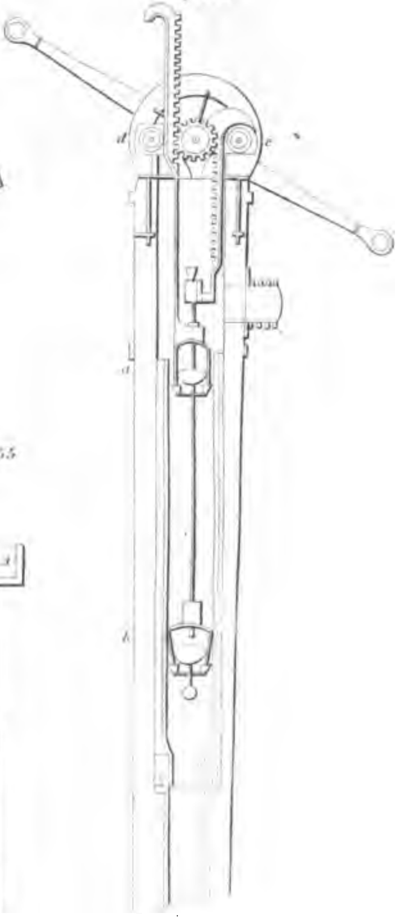

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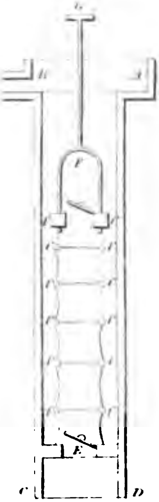

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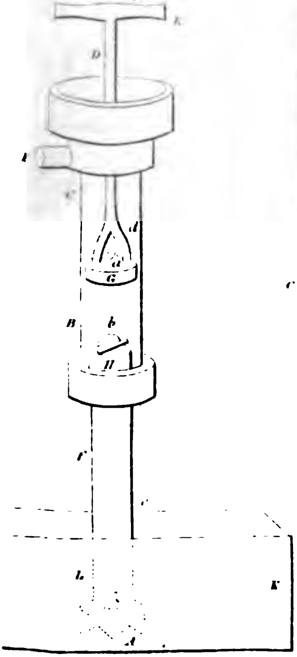

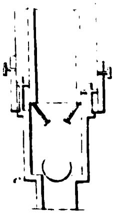

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[An account of this machine is likewise given in the Architecture Hydraulique of Belidor, tom. 2. and in the 2d vol. of Desaguliers' Experimental Philosophy: in both which performances many other hydraulic machines are described.]

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M. de Hautefeuille, Réflexions sur quelques Machines à élever les Eaux avec sa Description d'une nouvelle Pompe, sans Frottement et sans Piston, &c. 1682.

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A new Way of raising Water, enigmatically proposed, by Dr Papin. Phil. Trans. 1685, No. 173. The solutions by Dr Vincent and Mr R. A. in No. 177.

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D. Papin, Nouvelle Manière pour lever l'Eau par la Force du Feu: à Cassel. 1707.

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Sur l'Effet d'une Machine Hydraulique proposée par M. Segner, par M. Leon. Euler, Mem. Acad. Sci. Berlin. 1750.

Application de la Machine Hydraulique de M. Segner à toutes sortes d'ouvrages, et de ses advantages sur les autres Machines Hydrauliques, par M. Leon. Euler, Mem. Acad. Sci. Berlin. 1751.

[M. Segner's machine is no other than the simple yet truly ingenious contrivance known by the name of Barker's mill, which had been described in the 2d volume of Desaguliers' Philosophy, some years before the German professor made any pretensions to the honour of the invention. The theory of it is likewise treated by John Bernoulli at the end of his Hydraulics.]

Recherches sur une nouvelle manière d'élever de l'Eau proposée par M. de Mour, par M. L. Euler, Mem. Acad. Berlin. 1751.

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Nicander's Theorie der Spiral Pumpe. 1789.

Nouvelle Architecture Hydraulique, par M. Prony. 1790, 1796.

A short Account of the Invention, Theory, and Practice of Fire Machinery; or, Introduction to the Art of making Machines vulgarly called Steam-Engines, in order to extract water from mines, convey it to towns, and jets-d'eaux in gardens; to procure water-falls for fulling, hammering, stamping, rolling, and corn-mills; by W. Blakey. 1793.

PUMPS.

1. The construction of pumps is usually explained by glass models, in which the action both of the pistons and valves may be seen.

In order to understand the structure and operation of the common pump, let the model D C B L, fig. 222, be placed upright in the vessel of water K, the water being deep enough to rise at least as high as from A to L. The valve *a* on the movable bucket G, and the valve *b* on the fixed box H, (which box quite fills the bore of the pipe or barrel at H,) will each lie close by its own weight, upon the hole in the bucket and box, until the engine begins to work. The valves are made of brass, and covered underneath with leather, for closing the hole more exactly; and the bucket G is raised and depressed alternately by the handle E and rod D *d*, the bucket being supposed at B before the working begins.

Take hold of the handle E, and thereby draw up the bucket from B to C, which will make room for the air in the pump all the way below the bucket to dilate itself, by which its spring is weakened, and then its force is not equivalent to the weight or pressure of the outward air upon the water in the vessel K; and therefore at the first stroke, the outward air will press up the water through the notched foot A, into the lower pipe, as far as *e*: this will condense the rarefied air in the pipe between *e* and C to the same state as it was in before; and then, as its spring within the pipe is equal to the force or pressure of the outward air, the water will rise no higher by the first stroke; and the valve *b*, which was raised a little by the dilatation of the air in the pipe will fall, and stop the hole in the box H; and the surface of the water will stand at *e*. Then depress the piston or bucket from C to B, and as the air in the part B cannot get back again through the valve *b*, it will, (as the bucket descends,) raise the valve *a*, and so make its way through the upper part of the barrel *d* into the open air. But, upon raising the bucket G a second time, the air between it and the water, in the lower pipe at *e*, will be again left at liberty to fill a larger space; and so its spring being again weakened, the pressure of the outward air on the water in the vessel K will force more water up into the lower pipe from *e* to *f*; and when the bucket is at its greatest height C, the lower valve *b* will fall, and stop the hole in the box H as before. At the next stroke of the bucket or piston, the water will rise through the box H towards B, and then the valve *b*, which was raised by it, will fall when the bucket G is at its greatest height. Upon depressing the bucket again, the water cannot be pushed back through the valve *b*, which keeps close upon the hole whilst the piston descends. And upon raising the piston again, the outward pressure of the air will force the water up through H, where it will raise the valve, and follow the bucket to C. Upon the next depression of the bucket G, it will go down into the water into the barrel B; and as the water cannot be driven back through the now close valve *b*, it will raise the valve *a* as the bucket descends, and will be lifted up by the bucket when it is next raised. And now, the whole space below the bucket being full, the water above it cannot sink when it is depressed; but upon its depression, the valve *a* will rise to let the bucket go down; and when it is quite down; the valve *a* will fall by its own weight, and stop the hole in the bucket. When the bucket is next raised, all the water above it will be lifted up, and begin to run off by the pipe F. And thus by raising and depressing the bucket alternately, there is still more water raised by it; which getting above the pipe F, into the wide top I, will supply the pipe, and make it run with a continued stream.

So, at every time the bucket is raised, the valve *b* rises, and the valve *a* falls: and at every time the bucket is depressed, the valve *b* falls and the valve *a* rises.

As it is the pressure of the air or atmosphere which causes the water to rise, and follow the piston or bucket G as it is drawn up; and since a column of water 32 feet high is of equal weight with as thick a column of the atmosphere, from the earth to the very top of the air; therefore the perpendicular height of the piston or bucket from the surface of the water in the well must always be less than 32 feet; otherwise the water will never get above the bucket.

But when the height is less, the pressure of the atmosphere will be greater than the weight of the water in the pump, and will therefore raise it above the bucket; and when the water has once got above the bucket, it may be lifted to any height, if the rod D be made long enough, and a sufficient degree of strength be employed, to raise it with the weight of the water above the bucket without ever lengthening the stroke.

The force required to work a pump will be as the height to which the water is raised, and as the square of the diameter of the pump-bore in that part where the piston works. So that if two pumps be made of equal heights, and one of them be twice as wide in the bore as the other, the widest will raise four times as much water as the narrowest, and will require therefore four times as much strength to work it.

The wideness or narrowness of the pump in any other part besides that in which the piston works, does not make the pump either more or less difficult to work, except what difference may arise from the friction of the water in the bore, which is always greater in a narrow bore than in a wide one, because of the great velocity of the water.

The pump-rod is never raised directly by such a handle as E at the top, but by means of a lever, whose longer arm, (at the end of which the power is applied,) generally exceeds the length of the shorter arm five or six times, and by that means gives five or six times as much advantage to the power. Upon these principles, it will be easy to find the dimensions of a pump that shall work with a given force, and draw water from any given depth.

The quantity of water raised by each stroke of the pump-handle is just as much as fills that part of the bore in which the piston works, be the size of the rest of the bore above and below the piston what it will. The pressure of the atmosphere will raise the water 32 feet in a pipe exhausted of air; but it is advisable never to have the piston more than 20 or 24 feet above the level of the surface of the water in which the lower end of the pump is placed; and the power required to work the pump will be the same, whether the piston goes down to lie on a level with the surface of the well, or whether it works 30 feet above that surface, because the weight of the column of air that the piston lifts is equal to the weight or pressure of the column of water raised by the pressure of the air to the piston. And although the pressure of the air on the surface of the well will not raise or force up the water in the pump-bore more than 32 feet, yet when the piston goes down into the column so raised, the water gets above it, and may then be raised to any height whatever above the piston, according to the quantity of power applied to the handle of the pump for that purpose.

Pumps ought to be made so, (says Mr Ferguson,) as to work with equal ease in raising the water to any given height above the surface of the well. And this may be done by duly proportioning the diameter of the bore, (in that part where the piston works,) to the height the water is to be raised, as that the column of water may be no heavier in a long pump than in a short one, or indeed equally heavy in all pumps from the shortest to the longest, on a supposition that the diameter of the bore is the same size from top to bottom; and whatever size the bore be, above or below that part in which the piston works, the power required to work the pump will be just the same as if the bore was of the same size throughout.

In order that a man of common strength may raise water by pumps with the same ease, to any height not less than 10 feet, or more than 100 feet, above the surface of the well, Mr Ferguson has calculated the annexed table, in which the diameter of the bore is duly proportioned to the height; and in these calculations he supposes the pump-handle to be a lever increasing the power five times.

Height of the pump, in feet, above the surface of the well.	Diameter of the bore.		Water discharged in a minute, in wine measure.	
	Inches.	100 parts of an inch.	Gallons.	Pints.
10	6	.93	81	6
15	5	.66	54	4
20	4	.90	40	7
25	4	.38	32	6
30	4	.00	27	2
35	3	.70	23	3
40	3	.46	20	3
45	3	.27	18	1
50	3	.10	16	3
55	2	.95	14	7
60	2	.84	13	5
65	2	.72	12	4
70	2	.62	11	5
75	2	.53	10	7
80	2	.45	10	2
85	2	.38	9	5
90	2	.31	9	1
95	2	.25	8	5
100	2	.19	8	1

In the first column look for the number of feet the water is to be raised; then in the second column, you have the diameter of that part of the bore in which the piston or bucket works; and in the third column, the quantity of water which a man of ordinary strength can raise in a minute by the pump to the given height.

The quantity of water contained in a pipe of either of those heights in the table, supposing the diameter of the bore to be the same from top to bottom, is 4523.2 cubic inches, or 19.58 gallons in wine-measure, as near as the hundredth part of an inch in the diameter of the bore can make it.

Mr Ferguson has calculated the following table, by which the quantity and weight of water in a cylindrical bore of any given diameter and perpendicular height may be very readily found.

Diameter of the cylindrical bore 1 *inch*

Feet high.	Quantity of water in cubic inches.	Weight of water, in troy ounces.	In avoirdupoise ounces.
1	9.4247781	4.9712340	5.4541539
2	18.8495562	9.9424680	10.9083078
3	28.2743343	14.9137020	16.3624617
4	37.6991124	19.8849360	21.8166156
5	47.1238905	24.8561700	27.2707695
6	56.5486686	29.8274040	32.7249234
7	65.9734467	34.7986380	38.1790773
8	75.3982248	39.7698720	43.6332312
9	84.8230029	44.7411060	49.0873851

For tens of feet high, remove the decimal points one place towards the right hand; for hundreds of feet, two places; for thousands, three places; and so on. Then multiply each sum by the square of the diameter of the given bore, and the products will be the answer.

EXAMPLE:

Qu. What is the quantity and weight of water in an upright pipe 85 feet high, and 10 inches in diameter of bore? The square of 10 is 100.

Feet high.	Cubic Inches.	Troy ounces.	Avoirdupoise ounces.
80	753. 982248	397. 698720	436. 332312
5	47.1238905	24.8561700	27.2707695
85	801.1061385	422.5548900	463.6030815
Multiply by	. . . 100	100	100
Answer . .	80110.6138500	42255.4890000	46360. 308150

Which number, (80110.61,) of cubic inches being divided by 231, the number of cubic inches in a wine gallon, gives 342.6 for the number of gallons in the pipe; and 42255.489 troy ounces being divided by 12, gives 3521.29 for the weight of the water in troy pounds; and, lastly, 46360.3 avoirdupoise ounces being divided by 16, gives 2897.5 for the weight in avoirdupoise pounds.

The power required to work a pump, or any other hydraulic engine, must not only be equal to the whole column of water in the pump-bore, but as much superior to it as will overcome all the friction of the working parts of the engine.

2. In Dr Gregory's *Mechanics*, vol. ii. is the following description of a pump, with little friction, which may be constructed in a variety of ways by any common carpenter, without the assistance of the pump-maker, or plumber, and which will be very effective for raising a great quantity of water to small heights, as in draining marshes, marle pits, quarries, &c. or even for the service of a house.

A B C D, fig. 223, is a square trunk of carpenter's work open at both ends, and having a little cistern and spout at top. Near the bottom there is a partition made of board, perforated with a hole E, and covered with a dock. *f f f f* represent a long cylindrical bag made of leather or of double canvass, with a fold of thin leather, such as sheep skin, between the canvass bags. This is firmly nailed to the board E with soft leather between. The upper end of this bag is fixed on a round board having a hole and valve F. This board may be turned in the lathe with a groove round its edge, and the bag fastened to it by a cord bound tight round it. The fork of the piston-rod F G is firmly fixed into this board; the bag is kept distended by a number of wooden hoops or rings of strong wire, *f f*, *f f*, *f f*, &c. put into it at a few inches distance from each other. It will be proper to connect these hoops, before putting them in, by three or four cords from top to bottom, which will keep them at their proper distances. Thus will the bag have the form of a barber's bellows powder-puff. The distance between the hoops should be about twice the breadth of the rim of the wooden ring to which the upper valve and piston-rod are fixed.

Now let this trunk be immersed in the water. It is evident that if the bag be stretched from the compressed form which its own weight will give it by drawing up the piston-rod, its capacity will be enlarged, the valve F will be shut by its own weight, the air in the bag will be rarefied, and the atmosphere will press the water into the bag. When the rod is thrust down again, this water will come out by the valve F, and fill part of the trunk. A repetition of the operation will have a similar effect; the trunk will be filled, and the water will at last be discharged by the spout.

Here is a pump almost divested of friction, and perfectly light. For the leather between the folds of canvass renders the bag impervious both to air and water. And the canvass has very considerable strength. We know, from experience, that a bag of six inches diameter, made of sail-cloth No. 3, with a sheep-skin between, will bear a column of 15 feet of water, and six hours work per day for a month without failure, and that the pump is considerably superior in effect to a common pump of the same dimensions. We must only observe, that the length of the bag must be three times the intended length of the stroke; so that when the piston rod is in its highest position, the angles or ridges of the bag may be pretty acute. If the bag be more stretched than this, the force which must be exerted by the labourer becomes much greater than the weight of the column of water which he is raising. If the pump be laid aslope, which is very usual in these occasional and hasty drawings, it is necessary to make a guide for the piston-rod within the trunk, that the bag may play up and down without rubbing on the sides, which would quickly wear it out.

The experienced reader will see that this pump is very like that of Gosset and De la Deuille, described by Belidor, vol. ii. p. 120, and most writers on hydraulics. It would be still more like it if the bag were on the under side of the partition E, and a valve placed further down the trunk. But we think that our form is greatly preferable in point of strength. When in the other situation, the column of water lifted by the piston tends to *burst* the bag, and this with a great force, as the intelligent reader well knows. But in the form recommended here, the bag is *compressed*, and the strain on each part may be made much less than that which tends to burst a bag of six inches diameter. The nearer the rings are placed to each other the smaller will the strain be.

The same bag piston may be employed for a forcing-pump, by placing it below the partition, and inverting the valve; and it will then be equally strong, because the resistance in this case too will act by compression.

3. An ingenious variation in the construction of the sucking-pump, is that with two piston-rods, in the same barrel, invented by Mr Walter Taylor, of Southampton. A vertical section of this pump is given in fig. 224.

The piston-rods have racks at their upper parts working on the opposite sides of a pinion, and kept to their proper positions by friction-rollers. The valves used in this pump are of three kinds, as shown at *a*, *b*, and *c*. The former is a spheric segment which slides up and down on the piston-rod, and is brought down by its own weight; the second, *b*, is called the pendulum-valve; and the third, *c*, is a globe which is raised by the rising water, and falls again by its own weight. Each of these valves will disengage itself from chips, sand, gravel, &c. brought up by the water. In this kind of pump the pistons may either be put in motion by a handle in the usual way, or a rope may pass round the wheel *d e* in a proper groove, the two ends of which, after crossing at the lower part of the wheel, may be pulled by one man or more on each side. A pump of this kind, with seven inch bore, heaves a ton 24 feet high in a minute, with ten men, five only working at a time on each side.

Another improvement of the common pump has been made by Mr Todd, of Hull. This invention in some particulars bears a resemblance to the ordinary one, but he has contrived to double its powers by the following means:

Having prepared the piston-cylinder, which may be 12 feet high, he cuts from the bottom of it about three feet; at the end of the great cylinder he placed an atmospheric-valve, and to the top of a small cylinder a serving-valve. In the bottom of the small cylinder, which contains the serving-valve, is inserted an oblong elliptical curved tube, of equal caliber with the principal cylinder, and the other end is again inserted in the top of the great cylinder. This tube is divided in the same manner as the first cylinder, with atmospheric and serving-valves, exactly parallel with the valves of the first cylinder. The pump, thus having double valves, produces double effects, which effects may be still further increased by extending the dimensions.

The cylinder is screwed for service on a male tube screw, which projects from the side of a reservoir or water cistern, and is worked by hand.

The piston-plunger is worked by a toothed segment-wheel, similar to the principle of the one used in working the chain-pumps of ships belonging to the royal navy; and the wheel receives its motion from a hand-winch, which is considerably accelerated by a fly-wheel of variable dimensions, at the opposite end.

This pump, in addition to its increased powers, possesses another very great and prominent advantage. By screwing to it the long leather tube and fire-pipe of the common engine, it is in a few minutes converted into an effective fire-engine. Hence, whoever possesses one may be said to have a convenient domestic apparatus against fire. Three men can work it, one to turn the winch, another to direct the fire-pipe, and a third to supply the water.

4. The *Forcing-pump* is represented in fig. 225.

It raises water through the box H, not in the same manner as the sucking or lifting pump does, when the plunger or piston *g* is lifted up by the rod D *d*; but this plunger or forcer has no hole through it, to let the water in the barrel B C get above it, when it is depressed to B; and the valve *b*, (which rose by the ascent of the water through the box H when the plunger *g* was drawn up,) falls down and stops the hole in H the moment that the plunger is raised to its greatest height. Therefore as the water between the plunger *g* and the box H can neither get through the plunger upon its descent, nor back again into the lower part of the pump L *e*, but has a free passage by the cavity around H into the pipe M M, which opens into the air-vessel K K at P, the water is forced through the pipe M M by the descent of the plunger, and driven into the air-vessel, and in running up through the pipe at P, it opens the valve *a*, which shuts at the moment the plunger begins to be raised, because the action of the water against the under side of the valve then ceases.

The water being thus forced into the air-vessel K K, by repeated strokes of the plunger, gets above the lower end of the pipe G H I, and then begins to condense the air in the vessel K K. For as the pipe G H is fixed air-tight into the vessel below F; and the air has no way to get out of the vessel but through the mouth of the pipe at I, and cannot get out when the mouth I is covered with water, and is more and more condensed as the water rises upon the pipe, the air then begins to act forcibly by its spring against the surface of the water at H; and this action drives the water up through the pipe I H G F, from whence it spouts in a jet S to a great height, and is supplied by alternately raising and depressing the plunger *g*, which constantly forces the water that it raises through the valve H, along the pipe M M, into the air-vessel K K.

The higher the surface of the water H is raised in the air-vessel, the less space will the air be condensed into, which before filled that vessel; and therefore the force of its spring will be so much the stronger upon the water, and will drive it with the greater force through the pipe at F; and as the spring of the air continues whilst the plunger *g* is rising, the stream or jet S will be uniform as long as the action of the plunger continues; and when the valve *b* opens to let the water follow the plunger upward, the valve *a* shuts, to hinder the water, which is forced into the air-vessel, from running back by the pipe M M into the barrel of the pump.

If there was no air-vessel to this engine, the pipe G H I would he joined to the pipe M M N at P: and then the jet S would stop every time the plunger is raised, and run only when the plunger is depressed.

Mr Newsham's Water-engine, for extinguishing fire, (see Fire-engine,) consists of two forcing-pumps, which alternately drive water into a close vessel of air; and by forcing the water into that vessel, the air in it is thereby condensed, and compresses the water so strongly, that it rushes out with great impetuosity and force through a pipe that comes down into it; and makes a continued uniform stream, by the condensation of the air upon its surface in the vessel.

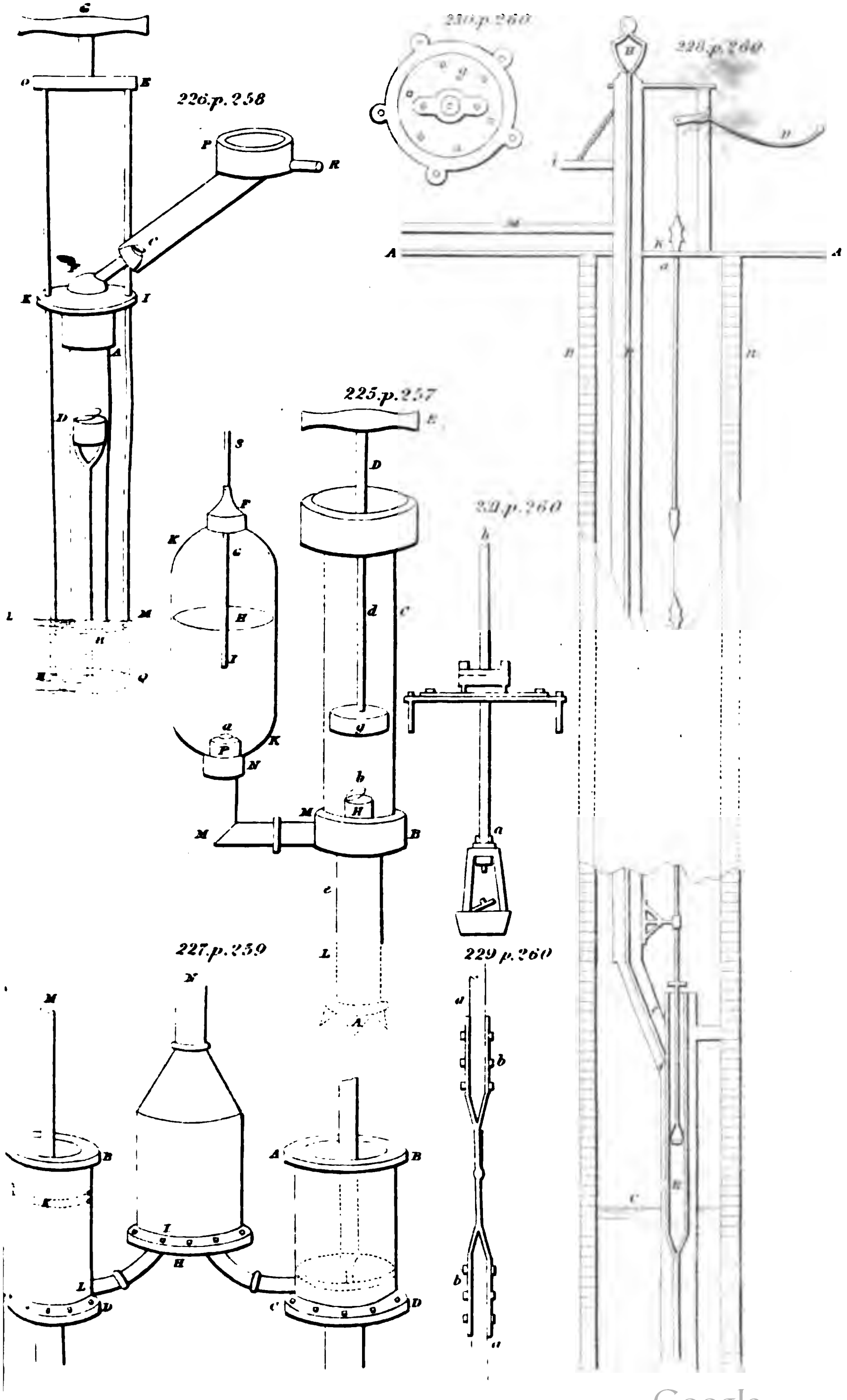
By means of forcing-pumps, water may be raised to any height above the level of a river or spring; and machines may be contrived to work these pumps, either by a running stream, a fall of water, by horses, or by steam.

The rod of the bucket in a sucking-pump is sometimes made to work through a collar of oiled leathers and brass plates, connected with the barrel of the pump by screws, and kept moist by water contained in a vessel at the top: it prevents the water issuing from the top of the pump, and therefore by a pipe it will raise to any height. This is called in the North a jackhead.

5. The *Lifting-pump* differs from the sucking-pump only in the disposition of its valves, and the form of its piston frame. This pump is represented in fig. 226.

A B is a barrel fixed in a frame I K L M, which is immovable, with its lower parts communicating with the water. G E Q H O is a frame with two strong iron rods, movable through holes in the upper and lower parts of the pumps I K and L M; in the bottom of this frame

PUMPS
From 225 to 231.



226. p. 258

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228. p. 260

229. p. 260

230. p. 260

231. p. 260

O Q H, is fixed an inverted piston B D, with its bucket and valve upon the top at D. Upon the top of the barrel there goes off a part F B, either fixed to the barrel, or movable by a ball and socket; but in either case water and air tight. In this part, at C, is a fixed valve opening upwards. It is evident that when the piston frame is thrust down into the water, the piston D descends, and the water below will rush up through the valve D, and get above the piston; and that, when the frame is lifted up, the piston will force the water through the valve C up into the cistern P, there to run off by the spout. The piston of this pump plays below the surface of the water. Mr Martin has described a mercurial pump, which works by quicksilver, invented by Mr Hoskins, and perfected by Mr Desaguliers; and another pump of the lifting sort, invented by Messrs Gosset and De la Deuille, and set up in the king of France's garden at Paris, the piston of which works without friction.—*Phil. Brit.* vol. ii. p. 57, &c. ed. 3.

6. *Ctesibius's pump*, the first of all the kinds, acts both by suction and pulsion.

Its structure and action are as follows: A brass cylinder A B C D, fig. 227, furnished with a valve in L, is placed in the water. In this is fitted an embolus M K, made of green wood, which will not swell in the water, and adjusted to the aperture of the cylinder with a covering of leather, but without any valve. In H is fitted on another tube N H, with a valve that opens upwards in I.

Now the embolus M K being raised, the water opens the valve in L, and rises into the cavity of the cylinder; and when the same embolus is again depressed, the valve I is opened, and the water driven up through the tube H N.

This is the pump used among the ancients, and that from which both the others are deduced. Sir S. Moreland has endeavoured to increase its force by lessening the friction, which he has done to good effect, insomuch as to make it work without almost any friction at all.

7. In 1813, the Society for the Encouragement of Arts' conferred a silver medal on Mr John Stevens, for an improvement in the construction of the forcing-pump, by which he is enabled, at a comparatively trifling expense, to raise water from a well 66 feet below the surface of the ground. The whole expense of the pump and apparatus was 25*l.*

The lower part of the pump-tree is four inches in the bore. The lower part of the rod which passes through the stuffing-box is made of brass; the elbow and upper pump-trees are of a two-inch bore, and may be easily made of any kind of wood. It may also be made to act as an engine to extinguish fires, by the addition of an air-tight vessel and pipe to the upper part.

In the drawing is introduced a cap and screw, in preference to screwing it to the nozle of the pump, as it is stronger and more to be depended upon; and when the water is to be raised a great height, a screw is also recommended to be made to fit the nozle, that every thing may be always ready for immediate use. The work of this pump is not liable to be injured by frost; and when the well is of considerable depth a brass or metal barrel for the piston to work in should be adopted.

Fig. 228 is a section of a well, in which a pump of this kind is fixed; A A represents the surface of the ground, and B B the brickwork of the well, in which the water stands at the level C, and is, by the pump, to be raised to the surface A A.

D is the lever or handle of the pump, which has the rod *a* jointed to it, and descending to the pump; the rod is made of wood, in several lengths, which are united by joints of iron, in the manner shown at fig. 229; the wooden rods, *a a*, being capped with iron forks *b*, which include the ends of them and are rivetted fast; the ends of the forks are joined together to connect the several lengths.

E is the working barrel, or chamber, of the pump, in which the bucket works; this part is formed of a tree, bored through and having a projecting branch *e*, which is likewise bored obliquely to the barrel, and forms the forcing pipe; in the bottom of the barrel the suction-valve is situated, being at the top of the suction part of the pump, which is bored with a smaller auger than the working chamber, which is also lined with a brass tube, where the bucket works. The top of the barrel is covered by a metal lid, *g*, (see figs. 230 and 231,) which has a stuffing-box in the centre to receive the metal cylindrical part of the pump-rod *h*; to the lower extremity of this the bucket *a* is fixed. The metal lid consists of a ring, which is screwed to the wooden barrel by five screw-bolts, passing through as many ears, projecting from the circumference of the ring; they have eyes below to hook upon pins, which are fixed in the wood, but project sufficiently for these bolts to hold, and are formed into screws above, so as to hold the ring firmly down, by means of nuts screwed upon them. The movable lid of the pump, which has the stuffing-box *g* formed in the centre of it, is screwed to the ring by five screws, and these can be taken out to remove the lid, and draw up the bucket, when it requires to be leathered.

F is the forcing pipe, formed of as many pieces of wooden pipes as are required to make up the length; they are united together by making the upper ends conical, to enter a similar cavity made in the lower end of the next pipe; the lowest piece fits upon the extremity of the projecting branch *e*, and a valve is proposed to be put in the pipe at this joint, to prevent the return of the water, and bear part of the weight of the column from the lowest valve at *f*; the upper end of the pipe has a spout *i*, at which the water is delivered.

M is a second spout, fixed into the pipe lower than the former; it has a screw by which it can be united to a hole, or leather pipe, to convey the water to a distance, or by means of a jet, or branch-pipe, to throw it in the manner of a fire-engine; in this case the upper spout *i* must be stopped up, by a screw-plug or cap; and there is a copper air-tight vessel H, situated at the top of the pipe F, to equalize the pulsative motion of the water as thrown by the pump.

K is a bracket fixed to the pipe F, and projecting over the centre of the pump, where it has a hole to receive the pump-rod *h*, and guide it steadily in its motion up and down, that it may not wear the stuffing-box away on one side. As the wooden tubes of which the forcing-pump F is composed may be made from waste or crooked timber, it makes a great difference between the low price of such, and that of the straight trees necessary for common pumps. A wooden plug may be chained to the pump, betwixt the spouts or nozels M and *i*, so as to be ready to stop that which is not wanted in use.

Mr Stevens is of opinion, that it is better to place the valve *f* above the level of the water in the well.

8. Mr William Tyror, of Liverpool, took out a patent in March 1819, for certain improvements in the construction of pumps, and in the machinery for working the same.

This improvement consists in having four brass chambers, marked P P P, fig. 232, joined together by means of breech-pieces with screws, and soldered across the joints; these breech-pieces, marked Q, Q, being cast of brass, or any other suitable metal. When these are complete, P P, fig. 233, is placed upon the breech-piece Q *q*, fig 234, and both of them are fixed to or under a box or frame suitable for the purpose.

This box or frame, fig. 238, is furnished with eight brass grooves, O O O, fastened to the sides with screws; and a crank, or four cranks in one, that is, one crank out of each side of the same piece of square iron or any other suitable metal, one up, one down, one in front, and one in back. To one end of the crank, or cranks, is fixed two tooth and pinion wheels, a sufficient distance apart to allow two wheels of the same diameter and thickness to stand between them, so that the cranks may go round without moving the other wheels, marked C and E. The wheels D and F are made fast on the cranks A, A, by means of a screw or pin, and the wheels C and E, being fixed close together, slide to and fro upon the square end of the axle U, by means of the guide or sliding geer V, which is fixed in a groove turned out of the nave of the wheel C, by means of a clip and two screws which fasten it underneath, and rests in the notches fixed at the other end of the box or frame, for the end of the guide or geer to rest.

The notches are three in number on each side of the box or frame W. The one farthest from the wheel has the guide V, drawn back, with the wheel E upon the small wheel F. By moving the guide into the middle notch, the wheels C and E are kept between the wheels D and F; and the notch nearest the wheels guides the wheel C on the large wheel D, so that the power is much greater when forcing or drawing water from a great depth.

When the wheels C and E are placed in the space between the lower wheels, the handle is moved from the upper axle U, and placed upon the end of the crank A A, and the pump is worked without the assistance of the wheels, as occasion may require. The machinery is furnished with four key-bow rods, marked B B B, for the purpose of fixing to them the spear boxes or plunging rods, by means of a joint and pin and bolt, the key-bow being filed square across in the inside, so as to give the roller-step a fair bearing.

Fig. 235 represents the rolling-step, which is formed of two pieces of brass, the one-half round, of a thickness according to the strength or size of the machinery; and the other round, like a wheel or sheave in form, and of the same thickness as the other half. This round sheave or wheel is cut half through the middle edgeways, and the piece is then cut off, and a dove-tail is cut down the width in proportion to the crank. The other half is then fitted into the place from whence the larger piece has been cut, and both of them are held together by means of two screws; and the sheave or wheel is then in the form of its appearance before it was cut. A hole is now drilled through the centre, and it is fixed upon the before mentioned crank or cranks. Y, in fig. 236, represents the larger half of this step; and X, fig. 237, represents the smaller half, with the dove-tailed standing upon it, which fills up the vacancy or room that is made in the large half for fixing it upon the crank.

The ends of each key-bow is set in the grooves, O O O, fig. 238, and the key-bow rods B B B B, work through holes in the bottom of the box, for which purpose an iron plate or base is formed with four holes, S S S, fig. 239, and is fixed at the bottom of the box or frame with screws. The rods, by being fitted into the holes in this plate, keep the stroke of the pump perpendicular, while the step rolls backwards and forwards in the key-bow, as they are forced up and down by the cranks moving or turning alternately round.

When this machinery is applied over a forcing-pump, or placed over a fire-engine, it causes a greater quantity of water to be discharged from the cistern or engine, and as it is very powerful, it is highly necessary that it should have a cock of a superior size, to let more water pass through in the same time than ordinary; for this purpose Mr Tyror makes the barrel, or that part of the cock where the key or stop goes in on one side, so that there is but one stop to the plug or key, the stop resting in that part that overhangs the side, admits of room for a full sized water-way to be completely through it, without causing the water to have any bubble or curl as it passes through the plug.

Reference to the figures:

Fig. 240 represents a side view of the cock.

Fig. 241, a top view of the same.

Fig. 242, the plug, with the water-way cut out.

Fig. 243 represents the crank, with the tooth and pinion wheels, and the rolling steps.

Fig. 244, the upper axle with the improved plan of the sliding geer.

Fig. 245, the spear box and rod in the form of the fastening at the top of the key-bow rod, when applied for shipping.

Fig. 246, a front view of the pump standing upon a ship's deck.

9. Mr Richard Franklin has been rewarded by the society of Arts for effecting certain improvements in the lifting and forcing pump, by which water can be conveyed into a cistern at the top of the house, to supply all the dressing-rooms, water-closets, &c.

A section of this pump is given in fig. 247.

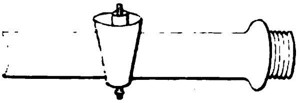
A A are two pistons; on the upper face of each is a double valve *v v v v;* the upper piston-rod passes through the stuffing-box B, and the lower through the stuffing-box C. S is the suction-pipe, and D the discharging-pipe.

Fig. 248 is an external view of the pump; *e e e* the lever or handle; F the fulcrum, on which the handle moves; G G is the pump-cylinder; *w w* the wheels which revolve between the standards *x x x x*, and which conduct the piston-rods parallel to the cylinder; *e p* the conducting rod, which conveys the motion of the handle to the lower piston; *e o* the conducting-rod which gives motion to the upper piston. It is evident, when the handle or lever is lifted, that the upper piston is pressed down, and the lower piston is at the same time elevated, with its valves shut, which forces the water through the upper piston and the discharging-pipe at the same operation.

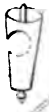
PUMP by TYROR

From 232 to 246

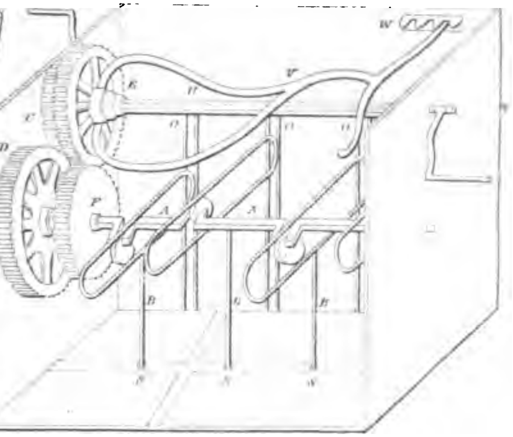
240.p.262



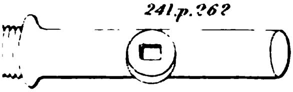
242.p.262



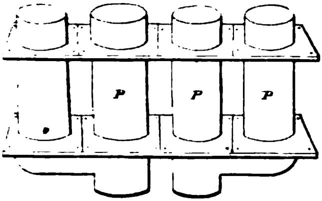
238.p.261,2



241.p.262



232.p.261



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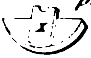
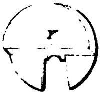
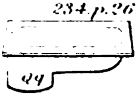


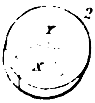
236 p.262



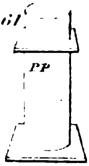
234.p.261



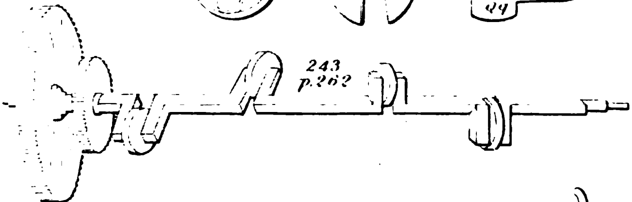
235 p.261



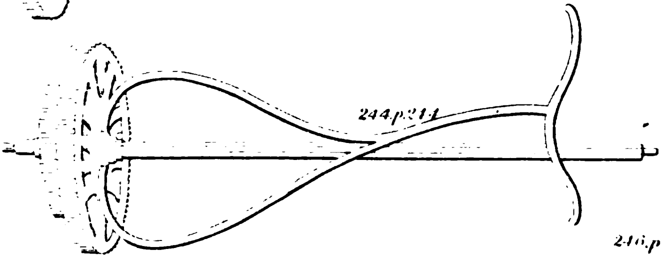
233.p.261



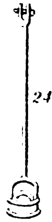
243 p.262



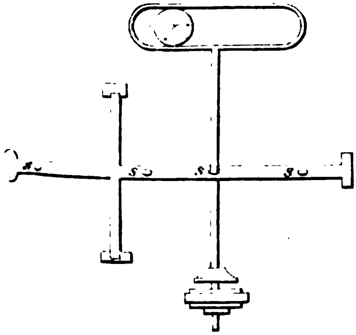
244.p.214



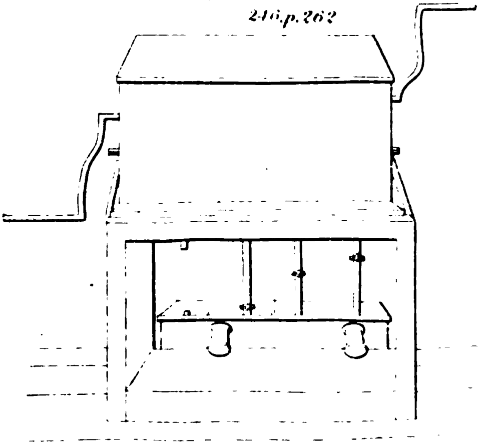
245.p.262



239.p.262



246.p.262



And when the handle is pressed down, the upper piston rises with its valves closed, and the water in its ascension is forced through the discharging pipe; at the same time the lower piston descends, by which action its valves are opened, and introduces a supply of water equal to the contents of the cylinder, minus the capacity of both pistons. The peculiar advantages of this pump with double pistons are, that with a six-inch stroke it discharges a quantity of water equal to twelve inches of the cylinder: and so, in this proportion, by always doubling the quantity of the stroke, whatever it may be; and thus furnishing a product just equal to two common pumps of the same stroke and capacity of cylinder, and certainly with less than a proportionable friction and expense.

10. The *pumps* that are usually employed *for draining mines* have many inconveniences, the principal of which we shall here proceed to describe.

1st. As it is necessary for the pumps, while sinking, to keep the water very low in the pit, the engine frequently goes too fast, in consequence of the pump drawing up air, and carries up by the violence of the current small pieces of stone, coal, or other substances, and lodges them above the bucket upon the valves, which must considerably retard the working of the pump, and wear the leather.

2dly. When the engine is set to work, (after having been stopped whilst working upon air, and consequently a quantity of air remaining in the pump-barrel, with the small stones, &c. deposited on the valves of the bucket,) it often happens that the compressure of the air by the descent of the bucket is not sufficient to overcome the weight of the bucket-valves so loaded with rubbish, and the column of water in the stand-pipes; the pump is thereby prevented from catching its water. The usual remedy for this is to draw the bucket out of the working-barrel, until a quantity of water has escaped by its sides to displace the air; this evil often arises from the unnecessary magnitude of the space between the bucket and the clack.

3dly. The pumps being suspended in the pit by capstan ropes, for the purpose of readily lowering as the pit is sunk, the stretching of the ropes, (especially when sinking in soft strata,) occasions much trouble, by suffering the pumps to rest on the bottom and choke; but the most serious evil is, that the miners, in shifting the pump from one place to another, that they may dig in all parts of the pit, throw them very far out of the perpendicular, thereby causing immense friction and wearing in all parts, besides endangering the whole apparatus, by breaking the bolts and stays, and straining the joints of the pipes.

These inconveniences have been obviated by Mr William Brunton, of Butterley Iron-works, in Derbyshire, who, to avoid the pump drawing air, has introduced a side pipe, connecting the parts of the working-barrel which are above and below the bucket, which pipe has a stop-valve, that the miners can regulate with the greatest ease, so as to keep the engine to its full stroke without drawing air, by letting down the water from the upper part of the barrel into the lower, so that it is working again in its own water. Instead of having the whole weight of the lower lift of pumps standing on the bottom, it is fixed in the pit by cross beams, and the miner has only to lift and move an additional pipe or wind-bore which slides upon the lower end of the pump like a telescope, to lengthen down, and this additional wind-bore is besides crooked, and turned aside like a short crank, which, by the facility with which it turns round in the leather collar about the nose of it, can easily be removed into every fresh hole which is made in the bottom by the miners. The pumps are supported in the pit by beams placed across at proper distances, so as to suit the lengths of the pipes, or lengths of the pump, which are nine feet. Short pieces are laid across these, with half circular holes in them, which being put round the pump, just beneath the flanches, firmly support its weight, but may quickly be removed, when it is required to lower the pumps in the pit; and as they are not fastened by any bolt, they do not prevent the pumps being drawn upwards, if it becomes necessary to take out the pumps when the pit is full of water.

The pumps by these means remain stationary, and the suction-pipe lengthens as the pit is sunk, until it is drawn out to its full extent; the whole column is then lowered to the next stanches, and another pipe is added to the top. The pumps being thus kept stationary till nine feet are sunk, the pipe at the top will of course deliver the water at the same level at all times, and instead of being obliged to lengthen the column at every yard sunk, it will only be necessary every nine feet.

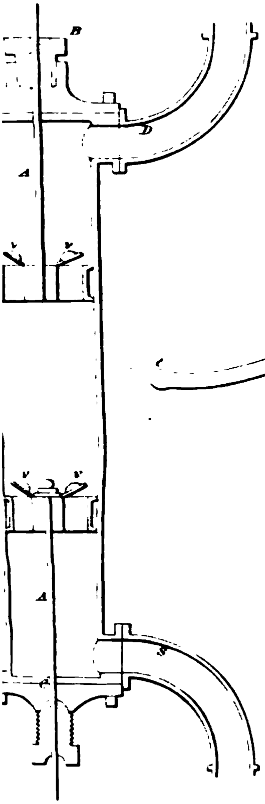
Fig. 249 explains the construction of Mr Brunton's pump, being a section through the centre of the working-barrel and suction piece. A is the door which unscrews to get at the clack of the pump; B is the working-barrel with the bucket D working in it; E is the clack, also shown in figs. 250 and 251; F is the suction-pipe, and G G a movable lengthening piece: this slides over and includes the other when the pump is first fixed; but as the pit is sunk, it slides down over the pipe F, to reach the bottom. The outside of the inner pipe F is turned truly cylindrical and smooth, and the inside of the outer pipe G, at the upper end for about six inches down, is made to fit it. The junction is made perfect by leathers being placed in the bottom of the cup *a a*; which holds water and wet clay over them, to keep them wet and pliable, and consequently air-tight. The lower extremity of the suction-pipe G terminates in a nose R, pierced with a number of small holes that it may not take up dirt. This nose is not placed in a line with the pipe, but curved to one side of it like a crank, so as to describe a circle when turned round.

By this means the miners, by turning it round upon the pipe F, can always place the nose R in the deepest part of the pit; and when they dig or blast a deeper part, they turn the nose about into it, the sliding tube lengthening down to reach the bottom of the hole, as shown in the figure. By this means there is never a necessity to set a shot for blasting so near the pump foot as to put it in any danger of being injured by the explosion, as is the case of the common pump, in which this danger can only be

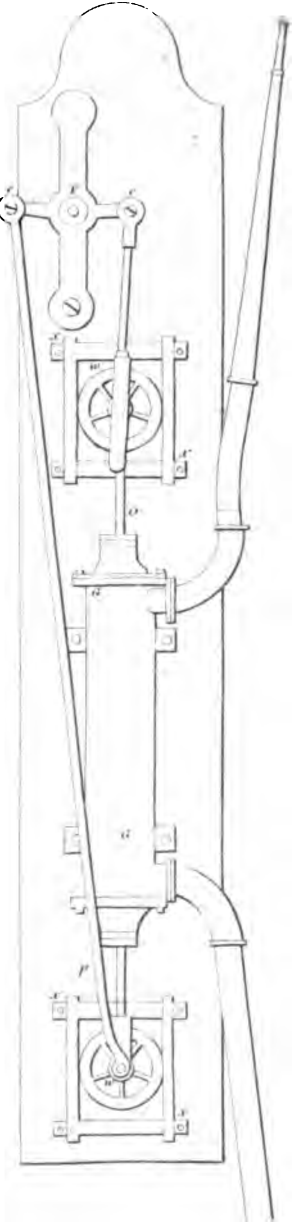
PUMPS

From 247 to 251.

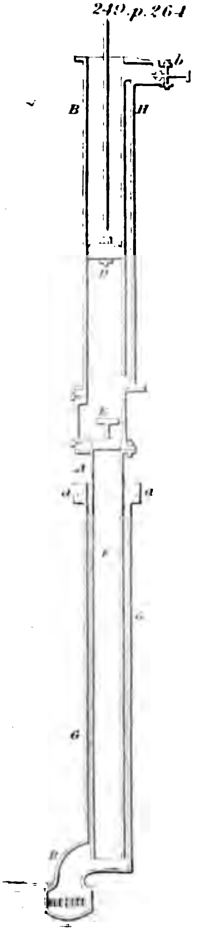
247. p. 262



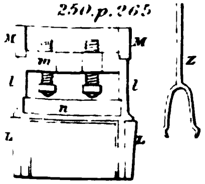
248. p. 262



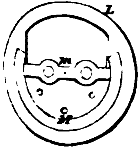
249. p. 264



250. p. 265



251. p. 265



avoided by moving the pump foot to one side of the pit, which necessarily throws the whole column of pumps out of the perpendicular.

The construction of the clack is explained by figures 250 and 251, the former being a section and the latter a plan. L L is a cast-iron ring, fitting into a conical seat in the bottom of the chamber of the pump, as shown in fig, 249; it has two stems, *l l*, rising from it to support a second iron ring M M; just beneath this a bar *m* extends across from one stem to another, and has two screws tapped through it; these press down a second cross bar *n*, which holds the leather of the valves down upon the cross bar of the ring L, and this makes it fast, forming the hinge on which the double valves open, without the necessity of making any holes through, as is common: but the chief advantage is, that by this means the clack can be repaired, and a new leather put in, with far less loss of time than at present, an object of the greatest importance; for in many situations the water gathers so fast in the pit, that if the clack fails, and cannot be quickly repaired, the water rises above the clack door, so as to prevent any access to it, and there is no remedy in the common pump but drawing up the whole pile of pumps, which is a most tedious and expensive operation.

In Mr Brunton's pump, the clack can at any time be drawn out of it, by first drawing out the bucket, and letting down an iron prong Z, which has hooks on the outside of its two points; this, when dropped down, will fall into the ring M, and its prongs, springing out, will catch the under side, and hold it fast enough to draw it up. Another part of Mr Brunton's improvement consists in the addition of a pipe H, (fig. 249,) which is cast at the same time with the barrel, and communicates with it at top and bottom, just above the clack; at the upper end the pipe is covered by a flat sliding plate, which can be moved by a small rod *b*, passing through a collar of leather; the rod has a communication by a lever, so that the valve can be opened or shut by the men in the bottom of the pit.

The object of this side pipe is to let down such a proportion of the water which the pump draws, as will prevent it drawing air; though, of course, the motion of the engine will be so adapted as not to require a great proportion of the water to be thus returned through the side pipe; yet it will not be possible to work the engine so correctly as not to draw some without this contrivance; and if it does, it draws up much dirt and pieces of stone into the pump, besides causing the engine to work very irregularly, in consequence of partially losing its load every time the air enters the pump. Another service of the side pipe is, to let water down into the chamber of the clack to fill it, when the engine is first set to work after the pumps have been standing still, and the lower part of the barrel and chamber are empty.

11. Figures 252 and 253 are a section and elevation of a three-barrel force-pump, of a very good construction, which was used by Mr Smeaton in the numerous water-engines which he erected at London-bridge, Stratford, and other places, for the supply of towns with water. It has the advantage of the valves being very accessible, and the water-way may be kept to the full size of the barrel without contractions,

which, as they occasion great resistance to the motion of the water, are a waste of power. It acts on the same principle as the ordinary forcing-pump, only that three barrels are connected together for the advantage of raising a constant stream of water.

A A are the barrels, which are bored out truly cylindrical. If the pump is small, the barrels are usually made of brass; but for larger work, cast-iron is used. From one side near the bottom of each, proceeds a curved pipe B, turning up, and ending with a flaunch, to screw to the under side of the forcing-chamber L. There is also, near the bottom at the opposite side of the barrel, a projecting neck or short pipe D, covered at the end by a door screwed on, that it may be removed to give access to the valve *m*, in the bottom of the barrel. The barrels have projecting rings or flaunches, by which they are screwed down upon the suction chamber H, which is common to all three barrels; it has a pipe from each of its rods terminating in a flaunch *h*, to screw on the pipes which bring the water to the pump. The upper flaunch, or top of the suction-chamber H, has three holes in it, one under each barrel, and each is covered by a valve shutting downwards, as is shown in the section, fig. 252. These valves are made of iron, to shut down upon hinges like a door, and are covered with leather at the lower side.

Mr Smeaton made his valves with the centre-pin of the hinge removed backwards from the hole which the valve covers, and it is also raised above the surface of the under side of the valve, by which means the valve opens in some degree on that side where the hinge is, as well as on the other, and any obstruction getting into the valve will be less liable to be detained, and will not have such a great leverage to break the hinge of the valve when the force of the water shuts it down, as it would if the hinge was on a level, and close to the edge of the hole, because the obstacle will not be so near the centre.

The hinge is fastened to the pump by the screw *w*, passing through the metal, and screwing into the hinge; this being withdrawn, and the door D opened, the valve is quite loose, and may be taken out to renew the leather. To give facility to this, the doors D are made oval, as shown in fig. 253. Another similar valve *n* is fitted at the top of each of the pipes B, to cover their apertures; they are all covered by a common forcing-chamber L, which is exactly similar to the suction-chamber, except that it has nozles R, in the top over each valve, and covered with doors to give access to them. The conducting-pipes are carried away from either end of the forcing-chamber, flaunches being provided to unite them. Each barrel is fitted with a piston or forcer M, which consists of three metallic plates secured to the rod: the middle plate is turned true, and fitted as accurately as possible to the barrel; the upper and lower plates are somewhat smaller. Two round pieces of leather, largerthan the barrel, are placed above and below the middle plate, being held fast between it and the upper and lower plates. When forced into the barrels, these leathers turn up and down round the upper and lower plates, forming two cups of leather, which accurately fit the barrel, and will not permit any fluid to pass by them.

The parts of the pump are fastened together by screws and nuts, as will be understood by inspection of the figures. The whole pump is supported on two ground-sills, and by means of two iron branches of the suction-chamber H, the whole pump is bolted down upon the ground-sills.

The action of this pump is simply this: when the piston or forcer of one barrel is raised, it causes a vacuum in it, and the pressure of the atmosphere forces the water up the suction-pipe H, (if not more than 30 or 33 feet,) opens the valve *m*, in the bottom of the barrel, and fills it with water; on the descent of the forcer, the lower valve shuts, and the forcing valve *n* opens, by the water the barrel contained being driven through it into the forcing-chamber L, and thence to any place whither the forcing-pipe is carried. On the reascent of the forcer, the lower valve *m* opens, and the shutting of the forcing-valve *n* prevents the water returning into the barrel. The three forcers work up and down alternately, so that while one barrel is sending water up the force-pipe, the others are lifting it up the suction-pipe, and the third continues the action in the interval, when the change of motion takes places between the two. In this manner the pump will raise a very constant stream of water, if the forces are worked in a proper manner; which is best done by means of cranks, placed at such an angle to each other, upon the same axis, that they will act in due succession.

12. English ships of war carry four chain pumps and three hand-pumps, all being fixed in the same well, which also includes the mainmast.

The chain-pump, (fig. 254,) is no other than a long chain A, with a sufficient number of pistons, *a*, called buckets or saucers, fixed upon it at proper distances; it passes downwards through a wooden tube B, and returns upwards in the same manner, on the other side D, the ends being united together. The chain is extended over two wheels, E and F, called sprocket-wheels; one is placed over the tubes B and D of the pump, and the other at the bottom in the space between the two tubes through which the chain ascends and descends. By turning the upper wheel E, the chain of buckets is put in motion, and the lower part of the wooden tube, in which the chain ascends, is lined with a brass barrel, in which the saucers are fitted. As they are continually ascending in this tube, they raise a constant stream of water, which runs off from the top of the ascending trunk, and is carried by a trunk through the ship's side into the sea. The pump is worked by a crank or winch G, fixed on the axis of the upper wheel, whereon several men may be employed at once; and thus it discharges in a limited time a much greater quantity of water than the common pump, and that with less inconvenience to the labourers.

13. The chain-pump now in use in the navy is of a very improved construction, compared with original chain-pumps. It was introduced by Mr Cole, under the direction of Capt. Bentinck. The chain of this machine is simple, and not much exposed to damage. It is exactly similar to that of the

fire-engine, and appears to have been first applied to the pump by Mr Mylne, to exhaust the water from the caissons at Blackfriars-bridge. It has thence been transferred to the marine by Capt. Bentinck, after having received some material additions to answer that service.

The links of the chain, (fig. 255,) are each formed of two long plates of iron, *e e*, with a hole at each end, and fixed together by two bolts, serving as pins for the joints. The buckets or saucers fixed upon it are two circular plates of brass, *g*, with a piece of leather between them. The sprocket-wheels for the chain are formed in the same manner as the trundles used in mills, by two iron wheels fixed at eight inches distance upon the axles, and united by several round iron bolts, forming a rest for the chain; and its links have hooks, *b*, which are taken by these bolts, and thus the chain is secured upon the wheel, to prevent it from jerking back when charged with a column of water.

This pump was a great improvement upon the old chain-pumps used in ships before, in which the chain was of too complicated a fabric, and the sprocket-wheels used to work it were deficient, in wanting some contrivance to prevent the chain from sliding or jerking back upon the surface of the wheel, which frequently happened when the buckets were charged with a considerable weight of water, or when the pnmps were violently worked. The links were too short, and the awkward manner in which they were connected, exposed them to a great friction in passing round the wheels: hence they were sometimes apt to break or burst asunder in very dangerous situations, when it was extremely difficult or impracticable to repair the chain.

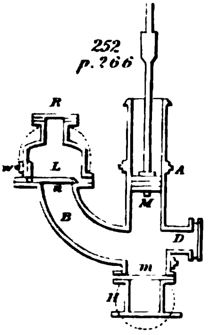
Mr Cole's pump is so constructed, that the chain may be easily taken up and repaired, when broken or choaked with ballast; and it discharges a much greater quantity of water with an inferior number of men, as appears from a trial of this machine with the old chain-pump, aboard the Seaford frigate, where it was found that its effects, when compared with the latter, were as follows:—The new pump with four men raised one ton of water in 43½ seconds, while the old pump required seven men to raise the same quantity of water in 76 seconds.

In this experiment the chain of the new pump was purposely broken, and dropped into the well, and afterwards taken up and repaired, and set to work again in two minutes and a half; then the lower wheel of the pump was taken out, to show how readily it might be cleared and refitted for action, after being choaked with sand or gravel, which could be performed in four or five minutes. These are advantages which, with a seaman, have a superior consideration to that

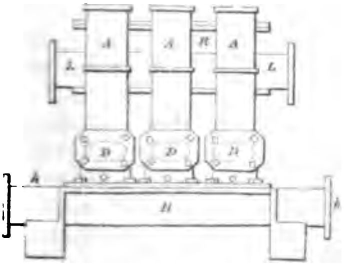
PUMPS

From 252 to 256.

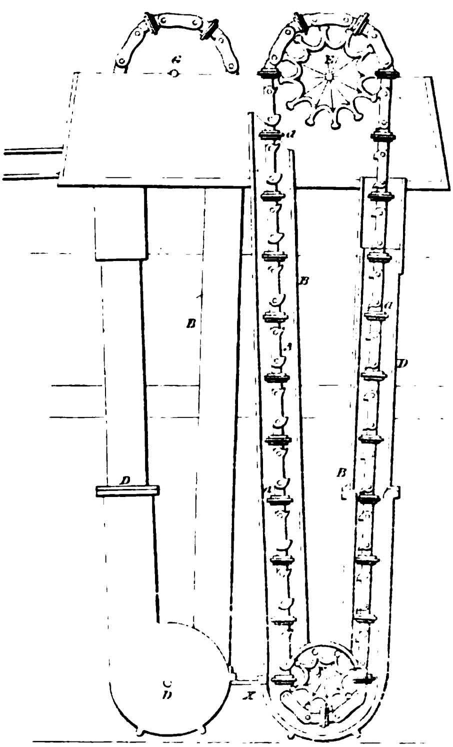
252 p. 266



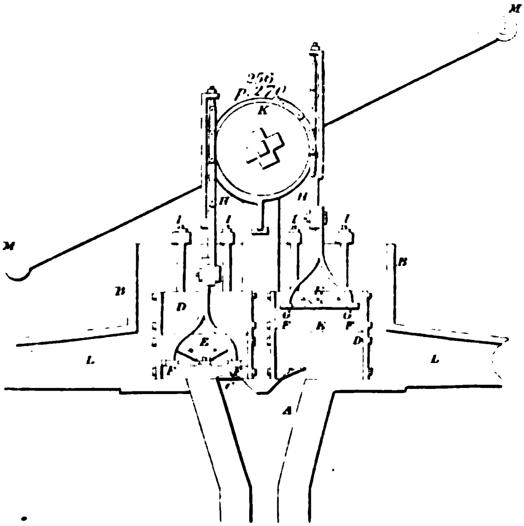
253. p. 266



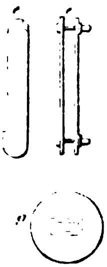
254. p. 267



256. p. 270



255. p. 268



of increasing the quantity of water which the machine will raise, unless it was in a considerable degree; and indeed the very best pumps will not raise a much greater proportion with the same power.

The only alteration which has been made on Mr Cole's pump, since its first introduction, near thirty years ago, is, that they now omit the lower sprocket-wheel altogether, the ascending and descending pipes being so united by a curved metal tube, that the chain passes better than if a wheel was used. The cranks are made to take off, and apply, when wanted, that they may not be in the way; they are long enough for thirty men to work at once; of late it has been proposed to add fly-wheels to them. This would be attended with but slight advantage, and several inconveniences from occupying that room where the men should stand to work, it being an object to employ as many as possible; but if they are crowded, they only incommode each other instead of assisting.

14. The following simple and ingenious method of working a ship's pump, when the crew are either too few in number, or too much exhausted to attend to that duty when the performance is most necessary, namely, in a heavy gale, was put in practice with great success by Capt. Leslie, of the ship George and Susan, on a late voyage from Stockholm to North America. He fixed a spar aloft, one end of which was ten or twelve feet above the top of his pumps, and the other projected over the stern; to each end he affixed a block or pulley. He then fastened a rope to the spears of the pump, and after passing it through both pullies along the spar, dropped it into the sea astern. To the rope he fastened a cask of 110 gallons measurement, and containing 60 or 70 gallons of water. This cask answered as a balance-weight, and every motion of the ship from the roll of the sea made the machinery work. When the stern descended, or when a sea or any agitation of water raised the cask, the pump spears descended; and the contrary motion of the ship raised the spears, when the water flowed out. The ship was cleared out in four hours, and the crew were of course greatly relieved.

15. *Hand-pumps* have been constructed in great variety for the use of ships; and as they are of great utility, we shall describe two or three of the best.

The ingenious Benjamin Martin invented a ship's pump with two barrels drawing from one suction-pump, so as to raise a contant stream.

This pump has so much merit, that we have given a section of it, fig. 256. Here A is the suction-pipe, conducting the water from the ship's hold up to the pump, where it is enlarged to communicate with both barrels D D, through the valves C C, in the bottom; E E are the pistons of the barrels, with double valves in them; they are not, like other pistons, fitted to slide in the barrels, but are simply brass rings, in which the valves are fitted, and being smaller than the barrels, have large circular pieces of leather fixed on them, the outside edges of which are attached to the insides of the pump-barrels; hence, when the pistons are moved up and down, the leather folds sufficiently to admit the motion, as is shown in the figure; but being close all round, these pistons can have no leakage or friction, and only a small resistance from the stiffness of the leather.

To fasten the edges of the leather piston to the barrels, they are made in two lengths, an upper and a lower, and the leather is introduced in the joint between them, being half fast, and the pump kept together by bars I I, fixed over the barrels, and bolts to press the upper length of the barrels down upon the lower. Both the barrels are included within a box or cistern B B, fixed upon the ship's deck, with trunks L L, which carry off the water as it runs over the tops of the barrels into the cistern. The pump is worked by piston-rods H H, being united by chains to a wheel K, the axle of which is supported by standards from the sides of the cistern B B, and is put in motion by the double lever M, at the end of which cross handles are fixed for several men to work at once. Mr Martin's pump acts extremely well; the constant stream raised by the alternate action of two barrels upon one pipe, produces an advantage that was shown by experiment, for the water not only rises while the piston rises, but continues to do so even after the piston begins to descend; and therefore the pump was found to deliver more water than was expected from the calculation of the contents of the barrel, and the number of strokes made.

To account for this, it must be considered, that as this pump has both its large pistons working, (alternately ascending and descending,) at the same time, there must be produced a constant rising column of water in the pipe, whose velocity through a bore of five inches, to supply the barrels of twelve inches diameter each, must be so great, that it cannot be checked or stopped at once, or upon the first descent of the piston; and therefore a surplus of water is produced. Notwithstanding these advantages of Mr Martin's pump, it has objections, which are serious obstacles to its use on board ships, though in other situations it is a good machine: these are, the shortness of its stroke, which renders it very fatiguing for men to work for a long time; but another more serious objection is, that the leather would, in general, remain dry, and thus become liable to harden and grow stiff, so as to break into holes when used at first, before they become soaked, and to fill the cistern first with water would be very troublesome.

16. The latest improvements in hand-pumps are by Capt. Jekyl, R. N. This gentleman has invented an addition to the pump of an air-vessel, and stuffing-box for the rod to pass

through, by which it will raise the water to a greater height than the head of the pump; and a hose being attached to the pump-spout, by very simple means, the water is conveyed to any part of the ship, and thrown in a jet through a hose-pipe with great force, to extinguish fire, if such a calamity should befall a ship; and thus the pump is rendered of twofold service. The idea of converting the pump to a fire-engine is not new, having been attempted in many different ways by forcing pumps; but these having pipes proceeding from the lower parts of the barrels and valves, which are not very accessible, are always liable to choke up by obstructions, and have not succeeded in general use. The air vessel has always been in the way, if made of a sufficent size to answer the purpose of equalizing the stream. Capt. Jekyl has obviated these objections, and without altering the material parts of the hand-pump, has rendered it as complete a fire-engine as can be wished.

This is explained by figure 257 which is a section of the pump through its whole length. A B C is the iron brake or lever to work it; it is branched to the extreme end, and has a wooden pole C, fixed in it, for several men to hold at once; D is the iron stanchion or fulcrum of the brake; it is fixed to the pump-head by means of strong iron hoops at E E and F F, which at the same time strengthen the work of the pump. The centre-pin is to be at the height of two feet six inches above the ship's deck. H are the slings of the pump, united by a forelock or pin to the end of the brake, and suspending the pump-spear I, by means of the joint-piece *g*. I K is the pump-spear, made of copper in the upper part I, and the lower length K of iron; the latter has the bucket M attached to it. The valve of the bucket is made in a very simple and effective manner, the valve being merely a round plate of brass, with a hole through the centre, to receive the rod upon which it rises and falls, and covers the aperture in the bucket. The bucket is a ring of brass, with a cross bar to fix the rod in; it is made in two thicknesses, one above the other, and a cup of leather is held in between them, projecting all round the upper part of the bucket, and turning up, to make a tight fitting in the barrel. The two rings of the bucket are held together by the piston-rod passing though both, and a cross wedge beneath. L is the brass chamber in which the bucket works; it is well fitted into the wood of the pump-tree; so that the water cannot leak by it, and is bored smooth withinside.

N is the lower box, fitted into the lower part of the pump-tree, beneath the chamber; it has a groove round it, into which oakum is placed, and when it is put down, makes a tight joint; its valve is of the same construction as that of the bucket, with the addition of a ring or eye on the top of the pin, on which the valve rises and falls. By this eye the box can be drawn up when it needs repair, by first drawing up the bucket of the pump, and putting an iron down into this eye. O O P is the air-vessel; this is a cylinder of sheet-copper, soldered to a cover of brass; within the centre of it is a tube likewise soldered to the cover, through which the copper pump-spear passes, and is fitted round at top with a collar of leather and stuffing. To prevent the escape of the water it is packed with hemp, and two rings of leather. R shows the place of two iron bars, fitted through the head of the pump, and confining the cover O O, of the air-vessel; they are fastened by the wedges *d;* it is by these only that the air-vessel is held down; a circle of leather is first put round the air-vessel, just beneath its lid, and this being pressed upon the recess in the wood, makes the joint tight. T is the pump nozle, which delivers the water. When it is used as a fire-engine, a hose is fixed on by its link-joints, and keys or wedges; the nozle is fixed to the pump by four screw-bolts going through the thickness of the pump, and it is fixed in such a direction as will most conveniently lead to a receiver, fig. 258, which unites the hose from all three of the ship's pumps.

Fig. 259 is the link-joint of the hose, T representing the pump-spout, made of cast-iron, and screwed to the pump-tree; *e e* is the collar or socket, made of brass, with the hose X bound upon it; this has two trunnions, on which a link *f* is fitted, one on each side; these links pass through grooves in the cast-iron piece T, and a key *g*, put down through the link behind it, draws the joint tight, without any screwing or further trouble. The socket *e e* is fitted into the nozle, and has a leather ring to make it tight. The outside of the pump is to be hooped at every three feet, to prevent it from bursting by the pressure of the water. The disposition of the three hand-pumps in a ship's well, renders their connection with a common receiver very convenient to bring all the water into one stream, which will then be very powerful, and more capable of extinguishing a fire than any movable engine.

Two hand-pumps are always placed on the starboard side of the mainmast, in the well; and one of them being the cistern-pump used for washing decks, its foot stands in a small cistern fixed upon the step of the mainmast, and supplied with water by a pipe through the ship's side, with a cock to admit it at pleasure; there is one pump on the larboard side of the mast. Three separate hoses being united with each of the pumps by a link-joint, like fig. 259, at one end, and with three necks *k k k,* of a receiver, fig. 258, by similar joints at the other, brings all the water into one, and a hose being joined by a link-joint, *l,* to the opposite end of the receiver, conveys the whole water to any part of the ship. The receiver has three nozles, *k k k,* at one end, made in a divergent direction, agreeable to the direction in which the hoses come from the three different pumps, and a valve is placed inside, before each hose, to open inwards, in order that the receiver may be used for one or two pumps, whilst the others are repairing or getting ready, or that if any of the hoses burst, the water may not escape from the receiver at the nozle. There are two handles fixed to the receiver, to lift and carry it, as it is to be movable; and when in use, is proposed to be laid upon the grating of the main hatchway, as the most central situation, from whence the hose may be carried in any direction. Z is a branch-pipe or jet, screwed at the end of the great hose X, and it also unscrews at the extreme end, to fit on jets of different bores, in the same manner as all other fire-engines. In working, the pressure of the water condenses the air contained within the receiver, O O P, into a small space, and its reaction to resume its former bulk equalizes the efflux of the water from the nozle of the pump.

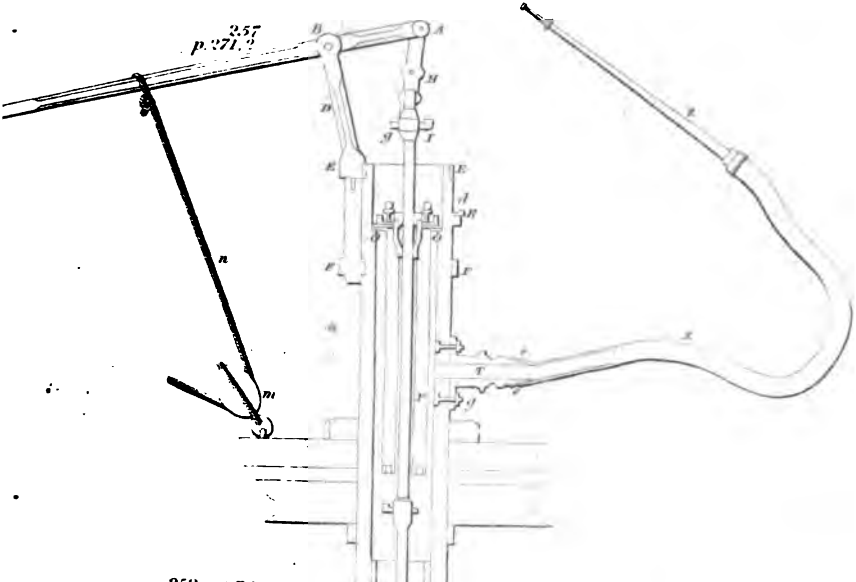
In some experiments which we have witnessed upon this pump, it performed as well as could be desired, a single pump forming a very effective engine; but when the three were combined, it was superior in force to any we have ever seen, and would throw a stream of an inch in diameter over the maintopmast-head of a 74-gun ship.

Besides the length of the handle C admitting several men to work at once, an accession of force is gained by a rope *n,* made fast to the brake A B,

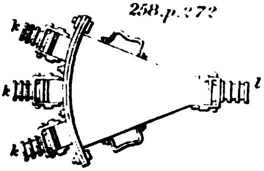
PUMPS

From 257 to 263

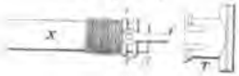
257
p.271.2



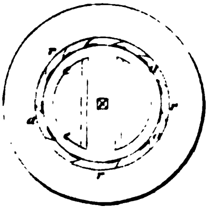
258.p.272



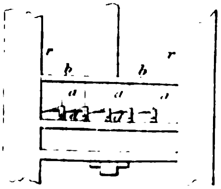
259.p.272



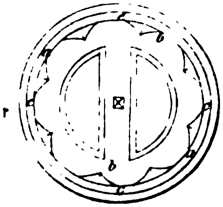
261.p.274



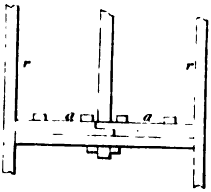
260.p.274



263.p.275



262.p.275



and conducted through a single block hooked to the deck at *m*, and thence along the ship's deck; at this any number of men may be employed very advantageously to produce the stroke, leaving those at the handle only to return it by lifting the handle. If the ship proves leaky, and the stuffing-box is thought to be an obstruction to the working of the pump, the air vessel may be taken out by drawing the wedge *d*, and taking out the bars R, which confine it; then after taking out the key which connects the joint-piece *g* with the copper rod, also removing the brake, lift out the air-vessel by the two screws of the stuffing-box, and fix on the joint-piece again, but fix the guide-eye H in the lowest pair of holes, so that it will receive the top of the copper rod, and prevent the pump-spear from having any play in the slings.

In this state it acts as a common hand-pump; but the air-vessel can be restored to its place, and be ready for work, in two minutes.

To prevent any of the work from being neglected from carelessness, the inventor proposes that one of the pumps shall be always used to wash the ship by the hose and jet every morning, which it would do much more effectually than by the present mode of raising the water into buckets; and the force with which the jet of water is thrown would very completely wash into every recess of the gun-carriages, and other places where a brush cannot reach; while by this constant exercise the pumps would be always ready, at a moment's notice, upon an alarm of fire.

17. Mr Robert Clarke, of Sunderland, has proposed a great improvement in the mode of applying men's force to pumping, which is worthy the consideration of seamen. It is to change the posture of standing to sitting, and making the action the same as that of rowing, which, besides that it is by philosophers considered as the most efficacious application of a man's force, it is to seamen most particularly so from their habitual practice of it. He objects to the ordinary action of pumping with a brake, as the posture is weak, and requires much force to preserve it. It oppresses the man by overstretching his loins on one side, and incommodes respiration by the flexture of the body on the other side. Too much motion of the shoulder-joint is required, as the muscles which act on the arm-bone at this joint are disproportionate to the effort they must make when the arm vibrates on the shoulder-joint as a centre, for the force to be communicated by the hand. Besides this, the arms themselves are at one instant enfeebled, by being thrown over the head, and requiring a pull, and the next instant require a pushing effort, which changes of direction in the exertion and restraining force are too continual and rapid for long continuance; in standing the body is a continued dead weight upon the legs.

The action of rowing is powerful to a surprising degree, and so well adapted to a man's ease, that he can continue it a greater length of time without fatigue than any other mode of exertion; for though the motion is large, it is made up of easy motions in several joints, the velocity and resistance of which suit the muscles employed. Very little sustaining force is required, for the body is supported, and returns unloaded to its charge: the breathing is free. The manner of carrying this into effect is very simple, the lever or brake being bent at right angles at a certain pin, so that it hangs straight down when it is at rest, instead of being horizontal; then to the lower extremity a rod is jointed, which is carried rather in an inclined direction upwards to the seaman, who is seated before the pump with a rest for his feet. The rod has a cross handle, to hold by both hands, and in some cases it may be made long enough for two men to sit side by side on the same seat; and by drawing and pushing it in the same manner as rowing, the perpendicular lever is caused to vibrate, and the horizontal arm or bended part, which suspends the pump-spear, partakes of the motion sufficiently for pumping.

18. M. de Bonnard, speaking of the *pistons of pumps*, in the *Journal des Mines*, states than the leather with which the external circumference of the pistons of pumps are covered, are quickly worn out by the continual friction which they undergo, and the renewing of them is an object of considerable expense in large mining undertakings.

They have therefore used in Saxony, for some years past, pistons without these external leathers in sucking-pumps, and to render the upper part of the piston elastic, by composing it of pieces of wood, which expand or open when the piston rises, and close when it descends.

To obtain this effect, the part of the piston which forms a bucket, is composed of a system of small movable pieces of wood *a a a*, figures 260 and 261, cut obliquely, and disposed, so as to cover each other nearly half their breadth; a leather which covers the upper suface of each of these pieces, serves to sustain them, and yet allow them sufficient play. To the under part of the same, pieces of leather are attached, which afford them all the elasticity that is necessary. These leathers are received into slits that are cut round the piston, and directed obliquely to its edges; they are fixed to the pieces of wood by nails, the extremities of which correspond with the notches *c c c*, and to the edges of the solid part of the piston by the screws *d d d*. By this disposition each piece of wood is movable upon a sort of horizontal hinge, and when the piston is raised, the weight of the water with which it is charged, by opening all these pieces, causes them to press one against the other, and against the sides *r r* of the barrel of the pump, so as not to let any of the water escape, and to produce completely the effect of a piston furnished with leather. The interior edges of each of the joints of the movable pieces are covered two by two with leather as at *e e e*, fig. 261, upon which the weight of the water acts as upon the pieces themselves.

All these leathers last a very long time, as well as those of the suckers, because they are not exposed to any friction, which only acts upon the movable pieces of wood. When the piston descends, the water that raises the suckers finds an easy passage, without filtering between the piston and the interior of the barrel of the pump; an effect which has this additional convenience, that no dirt can be introduced into the joints, which might afterwards prevent the perfect contact of the different pieces.

In 1808, these pistons were tried in several mines in Saxony, and were found very satisfactory. It was only observed that there was some inconvenience attending the use of them where the wells were much inclined; as the pressure of the water above not being equal upon all the movable pieces of the piston, those that were least pressed upon let some of the water pass between them. These inconveniences however exist only in the ordinary pistons.

In some departments pistons with springs are sometimes used, which are composed of movable rubbing-pieces, that are substituted for the leathers that are ordinarily employed. We know that these pistons are used with advantage in the cylinders of some blowing-engines; but in these pistons the rubbing-pieces are constantly forced against the interior surface of the cylinder by the springs.

In the piston with the flexible crown of wood, which M. Bonnard has described, the movable pieces of wood that compose it do nót rub against the interior surface of the barrel of the pump, except when the piston ascends, being then pushed by the weight of the column of water that is raised, and they scarcely rub at all against the surface when the piston descends. This peculiar effect assimilates this piston with those that have a flexible crown of léather, or a bucket, and gives it a decided advantage over pistons with springs and cushions. In other departments pistons with springs are sometimes used, which move in cylinders of cast-iron.

These pistons are composed of four pieces of brass, *a a a a*, figures 262 and 263, which are each about three centimetres in height and thickness, and are pushed horizontally by two springs, *b b b b*. Those pieces, which we shall call quadrants, in order that none of the air may escape when they play under the inequalities of the cylinder in which they rise and descend, are each of them something longer than a quarter of the circumference of the cylinder, and towards the extremities they are reduced to half the thickness.

By this means, these quadrants are perfectly covered at the extremities, and prevent the passage of the air in a horizontal direction, while the springs *b b b b* prevent its passage vertically.

In conclusion we shall observe, that these pistons, perfectly joined, have been proved to be proper for driving air with great force. We shall likewise observe, that the quadrants *a a a a* being made of brass, and rubbing against cast-iron, ought to last a very long time; consequently, the blowing here mentioned have the advantage of not requiring frequent repairs.

19. The following piston, described and recommended by Belidor, seems as perfect as the nature of things will allow. We shall therefore describe it in the author's own words, as a model which may be adopted with confidence in the greatest works.

"The body of the piston is a truncated metal cone, (fig. 264,) having a small fillet at the greater end. Fig. 265 shows the profile, and fig. 266 the plan of its upper base, where appears a cross bar D D, pierced with an oblong mortise E for receiving the tail of the piston-rod. A band of thick and uniform leather A A, (figs. 265 and 267,) is put round this cone, and secured by a brass hoop B B, firmly driven on its smaller end, where it is previously made thinner to give room for the hoop.

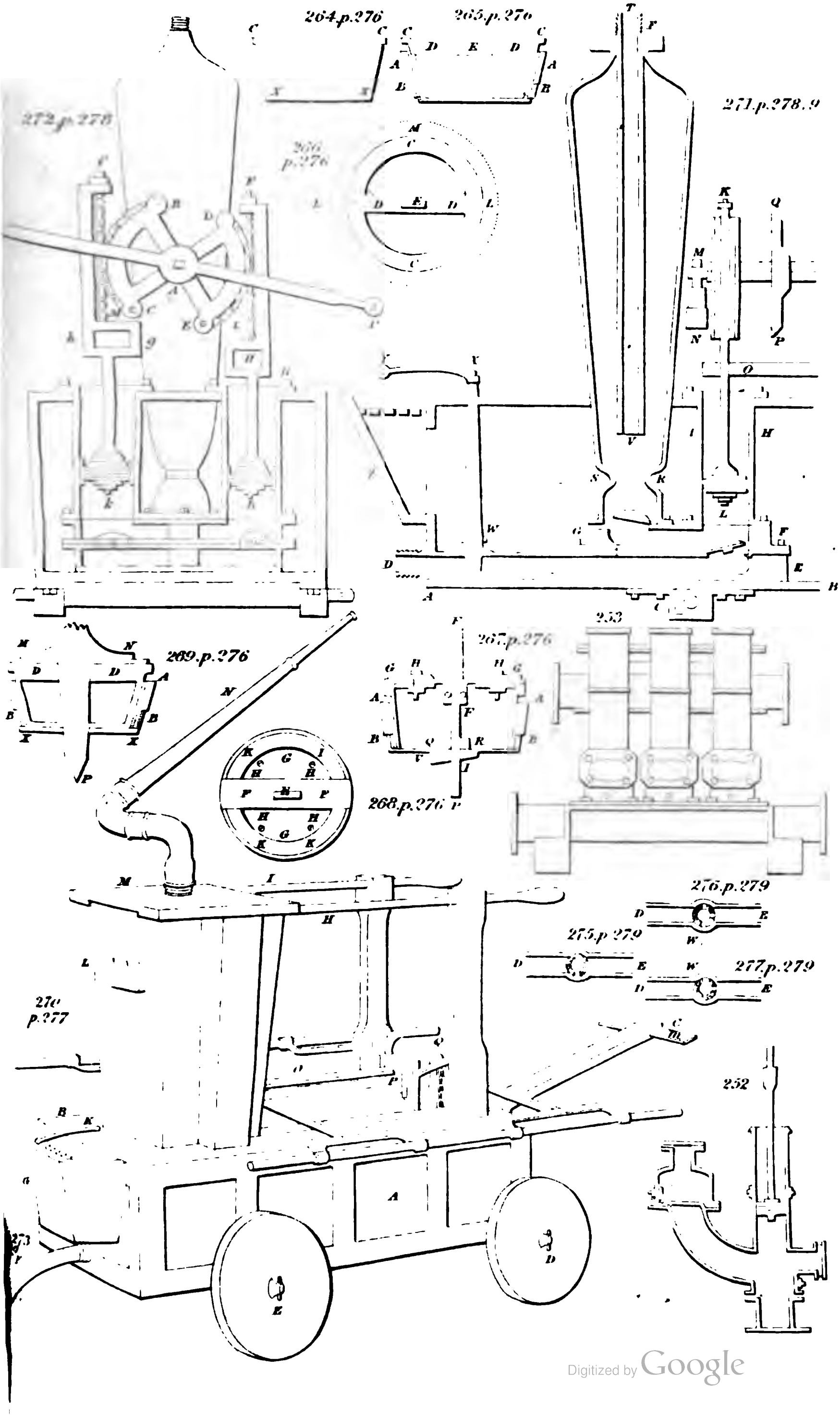
"This piston is covered with a leather valve, fortified with metal plates G G, (fig. 268.) These plates are wider than the hole of the piston, so as to rest on its rim. There are similar plates below the leathers, of a smaller size, that they may go into the hollow of the piston; and the leather is firmly held between the metal plates by screws H H, which go through all. This is represented by the dotted circle J K. Thus the pressure of the incumbent column of water is supported by the plates G G, whose circular edges rest on the brim of the water-way, and thus straight edges rest on the cross-bar D D of figs. 265 and 266. This valve is laid on the top of the conical box in such a manner that its middle E P rests on the cross-bar. To bind all together, the end of the piston-rod is formed like a cross, and the arms M N, (fig. 269,) are made to rest on the diameter F F of the valve, the tail E F going through the hole E in the middle of the leather, and through the mortise E of the cross-bar of the box, as well as through another bar, Q R, (figs. 267 and 268,) which is notched into the lower brim of the box. A key V is then driven into the hole I, in the piston-rod; and this wedges all fast. The bar Q R is made strong; and its extremities project a little, so as to support the brass hoop B B, which binds the leather band to the piston-box."

This piston has every advantage of strength, tightness and large water-way. The form of the valve, (which has given it the name of the *butterfly-valve*,) is extremely favourable to the passage of the water; and as it has but half the motion of a complete circular valve, less water goes back while it is shutting.

NEWSHAM'S FIRE ENGINE

Pl. 34.

From 264 to 277.



FIRE-ENGINES.

When fire breaks out in a crowded neighbourhood, it carries with it such devastating effects, that any individual who has seriously turned his attention to the constructing of an engine that is in the least calculated to check its progress, must ever be considered as deserving of our praise. Those who have most beneficially directed their attention this way are Messrs Newsham and Rowntree, whose engines we shall now proceed to describe.

1. A perspective view of Mr Newsham's fire-engine, ready for working, is represented in fig. 270.

It consists of a cistern A B, about three times as long as it is broad, made of thick oaken planks, the joints of which are lined with sheet copper, and easily movable by means of a pole and cross-bar C *m*, the fore part of the engine, which is so contrived as to slip back under the cover of the cistern and on four solid wheels, two of which are seen at D and E. The hind axle-tree to which the wheel E and its opposite are fixed, is fastened across under the bottom of the cistern; but the fore axle-tree, bearing the wheel D, &c. is put on a strong pin or bolt, strongly fastened in a horizontal situation in the middle of the front of the bottom of the cistern, by which contrivance the two fore-wheels and the axle-tree have a circular motion round the bolt, so that the engine may stand as firm on rough or sloping ground as if it were level.

Upon the ground next to the hind part of the engine may be seen a leather pipe F, one end of which may be screwed on and off upon occasion to a brass cock at the lower end of the cistern; the other end is immersed in water, supplied by a pond, fire-plug, &c. and the pipe becomes a sucking-pipe for furnishing the pump of the engine by its working, without pouring water into the cistern. To the hind part of the cistern is furnished a wooden trough G, with a copper grate for keeping out stones, sand, and dirt, through which the cistern is supplied with water when the sucking-pipe cannot be used. The fore part of the cistern is also separated from the rest of its cavity by another copper grate, through which water may be poured into the cistern. Those that work the pumps of this engine move the handles, visible at the long sides, up and down, and are assisted by others who stand on two suspended treadles, throwing their weight alternately upon each of them, and keeping themselves steady by taking hold of two round horizontal rails H I, framed into four vertical stands which reach the bottom of the cistern, and are well secured to its sides.

Over the hind trough there is an iron handle or key K, serving to open or shut a cock placed under it on the bottom of the cistern, the use of which we shall explain in the sequel of this article. L is an inverted pyramidal case which preserves the pumps and air-vessels from damage, and also supports a wooden frame M, on which stands a man, who, by raising or depressing, and turning about the spout N, directs the stream of water as occasion requires. This spout is made of two pieces of brass pipe, each of which has an elbow; the lower is screwed over the upper end F, (fig. 271,) of the pipe that goes through the air-vessel, and the upper part screws on to the lower by a screw of several threads, so truly turned as to be water-tight in every direction. The conic form of the spouting pipe serves for wiredrawing the water in its passage through it, which occasions a friction that produces such a velocity of the jet as to render it capable of breaking windows, &c. whilst the valves and leather pipes of the engine have sufficient water-way to supply the jet in its greatest velocity. Leather pipes of considerable length may be screwed at one end of the nozle of the engine, and furnished at one end with a wooden or brass pipe for guiding the water into the inner parts of houses.

Between the pyramid-box L, and the fore end of the engine, there is a strong iron bar O, lying in a horizontal position over the middle of the cistern, and playing in brasses supported by two wooden stands; one of which, P, is placed between the two fore stands of the upper rails, and the other is hid in the enclosure over the hind part. Upon proper squares of this bar are fitted, one near each end, two strong brass bars, which take hold of the long wooden cylindrical handles, by means of which the engine is worked; and the treadles by which they are assisted are suspended at each end by chains in the form of a watch-chain; and receive their motion jointly with the handles, that are on the same side, by means of two circular sectors of iron fastened together, and fixed upon proper squares of the middle horizontal bar; the two fore ones may be seen at Q; the two hind ones, represented upon a large scale in fig. 272, differ from the former only in thickness, for the fore sectors are made to carry only one chain each, fastened by one end to their upper part, and by the lower end to the treadles; whereas the sole of the two hind sectors is wide enough to carry two chains each; one set fastened like those of the fore ones for the motion of the treadles; and the other two chains are fastened by their lower ends to the lower part of these sectors, and by their upper ends to the top of the piston-bars, in order to give them motion. See fig. 271, in which the hind sectors and their apparatus are represented as they would appear to a person standing between the two fore wheels, and looking at the hind part of the engine.

The square over the letter A is the section of the middle bar, on which, right over the two barrels, are placed the two sectors B C A and D E A, forged together. F G H K and *f g h k* are the two piston-rods; and the openings between the letters G H and *g h*, are the spaces through which the hind parts of the two treadles pass. L and M represent two strong studs, rivetted on the other side of the bars on which they are placed; and to each of these is fastened a chain like a watch chain; and fixed by their upper ends to the upper extremities D and B of the iron sectors, by which they are drawn up and down alternately. These sectors give also an alternate motion up and down to the piston-rods, by means of two other chains, less white in the figure, in order to distinguish them from the others; these are fastened by their lower ends to the lower extremities of the sectors E and C, and their upper ends, terminating in a male screw, are made tight to the piston-rods at F and *f*, by two nuts.

The shape of the piston-rods, and the size and situation of the chains that give them motion, are so contrived, that the vertical axis of the piston is exactly in the middle of the breadth of the perpendicular part of the chains and the upper part of the piston-rod taken together. P Q represents one of the two cross-bars through the ends of which pass the handles to which the men apply their hands when they work the engine; these cross-bars are fitted on the middle bar at some distance from the sectors.

The other parts of this useful engine may be understood by the help of fig. 271, which represents the vertical section taken through the middle line of the hind part of the engine, as also the section of the air vessel, and that of one of the barrels, and likewise the profiles of the hind sectors, and several other parts. A B is the section of the bottom of the cistern, and C that of the hindmost axle-tree. D E is the vertical section of a strong piece of cast brass or hard metal, so worked as to have a hollow in it, represented by the white part, and fixed to the bottom of the cistern; this reaches from the opening D, through the cock W, and afterwards divides itself into two branches, so as to open under the two barrels; one of these branches is exhibited in the figure, and the other is exactly behind this. Through this channel, which may be called the sucking-piece, water is conveyed to the pumps by the pressure of the atmosphere, either from the cistern itself, or from any place at a distance, by means of the leather pipe F, fig. 273, which screws on the sucking-piece at D, fig. 271, under the hind trough Z, the grate of which is represented by the horizontal strokes. F G represents the vertical section of another piece of cast brass or hard metal, that may be called the communication-piece, having two hollows for conveying the water from under the pistons to the two openings of the flanch of the air-vessel; one of these hollows appears in the figure; the other lies exactly behind this, though not in a parallel direction. Between the section of the sucking-piece D E, and that of the communication-piece F G, may be observed the section of one of the plates of leather, which makes all tight, and forms one of the two sucking-valves, of which there is another just behind this, under the other barrel. R S T is the section of the copper air-vessel, and T V that of the conduit-pipe; this vessel is screwed on to the hind part of the communication-piece, and at top is fastened by a collar of iron to a cross piece of timber.

Between the flanch of the air-vessel and the communication-piece, may be observed the section of one of the plates of leather, making all tight, and screwing one of the two forcing valves, of which there is another just behind this, exactly over the other opening of the communication from the air-vessel. These valves are loaded with a lump of cast-iron or lead, having a tail or teat let through the flap of the valve, and cross pinioned under it: and it is to be observed, that though both the valves are represented open in the figure, they are never both open at the same time; for when the engine is not at work, they are closed down by the weights on their upper surfaces; and when the engine works, two are shut, and the other two are alternately opened by the motion of the pistons and the action of the atmosphere, together with the reaction of the air contained in the air-vessel.

H I is the section of one of the barrels of the two pumps, which are both sucking and forcing; as is evident from the position of the valves and the structure of the pistons, each of which is composed of two iron plates, of two wooden trenchers, and of two flat pieces of leather turning one up and the other down. L K represents one of the piston-rods edgewise, behind which is one of the chains, the top screw of which, K, can only be seen. M is the end of the middle bar, and N a section of the hindmost of the two middle stands which support the middle bar. O represents the end of the profile of one of the treadles, passing through the rectangular holes of the piston-rods, as in fig. 272. The weight on these treadles brings them and the piston-rods down alternately, and they are raised up again by the help of the other set of chains, one of which may be seen edgewise in this figure, placed on the sole of one of the sectors, &c. see fig. 272.

P Q is part of the cross-bars which carry the handles, seen edgewise, and X Y represents an iron handle, by the help of which the cock W may be placed in the several situations requisite for the use of the engine. The mechanism may be understood by figs. 275, 276, and 277, which represent the horizontal section of it, in three different situations. It has three holes, which are left white in these figures. In fig. 275, the position of the cock is represented when the handles X Y or K are in a direction parallel to D E, or to the middle bar, as in figs. 270 and 271. In this position the water supplied by the sucking-piece enters at D, and proceeds directly through the cock W to the valve under the two pistons; and there is now no communication from the barrel with the cavity of the cistern.

In fig. 276, we have the position of a cock when the handle X Y is turned one quarter of a revolution towards the eye from the last-mentioned situation, in which case there is no communication from the barrels with the outer extremity of the sucking-piece, but the water poured into the fore and hind trough, and passing from thence into the cavity of the cistern, enters the cock sideways, at W, and turning at right angles through the cock towards E, proceeds to the barrels of the pumps. Fig. 277* represents the cock W when the handle is placed diametically opposite to its last situation, in which case there is no communication from the under side of the barrels with the cavity of the cistern or the outward end of the sucking-piece; but this situation affords a communication from the cavity of the cistern with the outside of the engine, and the water left in the cavity of the cistern may by this means be employed when the engine has done working. These engines are made of five or six different sizes.

The principles on which this engine acts, so as to produce a continued stream, are obvious: the water being driven into the air-vessel, as in the operation of common sucking and forcing pumps, will compress the air contained in it, and proportionably increase its spring, since the force of the air's spring will be always inversely as the space which it possesses; therefore when the air-vessel is half filled with water, the spring of the included air, which in its original state counterbalanced the pressure of the atmosphere, being now compressed into half the space, will be equal to twice the pressure of the atmosphere; and by its action on the subjacent water will cause it to rise through the conduit-pipe, and play a jet of 32 or 33 feet high, abating the effect of friction. When the air-vessel is two-thirds full of water, the space which the air occupies is only one-third of its first space; therefore its spring being three times as great as that of the common air, will project the water with twice the force of the atmosphere, or to the height of 64 or 66 feet. In the same manner when the air-vessel is three-fourths full of water, the air will be compressed into one-fourth of its original space, and cause the water to ascend in air with the force of three atmospheres, or to the height of 96 or 99 feet, &c. as in the following table:

Height of the water.	Height of the compressed air.	Proportion of the air's spring.	Height to which the water will rise.
$\frac{1}{2}$	$\frac{1}{2}$	2	33 feet.
$\frac{2}{3}$	$\frac{1}{3}$	3	66
$\frac{3}{4}$	$\frac{1}{4}$	4	99
$\frac{4}{5}$	$\frac{1}{5}$	5	132
$\frac{5}{6}$	$\frac{1}{6}$	6	165
$\frac{6}{7}$	$\frac{1}{7}$	7	198
$\frac{7}{8}$	$\frac{1}{8}$	8	231
$\frac{8}{9}$	$\frac{1}{9}$	9	264
$\frac{9}{10}$	$\frac{1}{10}$	10	297

2. The fire-engine by Rowntree is a double force-pump, of a peculiar construction, similar in its action to the beer-engine, but as it is on a much larger scale, its constructions are of course varied.

In this engine, figs. 278 and 279 are two elevations at right angles to each other, of the external part of the engine, mounted on four wheels. Figs. 280 and 281 are two sections perpendicular to each other of the body of the engine or pump; figs. 282 and 283 are parts of the engine. The same letters are used as far as they apply in all the figures; A A A A, figs. 280 and 281, is a cast-iron cylinder truly bored, 10 inches diameter and 15 long, and having a flanch at each end whereon to screw two covers, with stuffing-boxes, *a a*, in their centres, through which the spindle, B B, of the engine passes, and being tight packed with hemp round the collar, makes a tight joint; the piston D is affixed to the spindle within the cylinder, and fits it tight all round by means of leathers; at E, fig. 281, a partition, called a saddle, is fixed in the cylinder, and fits against the back of the spindle tight by a leather.

We have now a cylinder, divided by the saddle E and piston into two parts, whose capacity can be increased and diminished by moving the piston, with proper passages and valves to bring and convey the water; this will form a pump. These passages are cast in one piece with the cylinder: one, *d*, for bringing the water, is square, and extends about one-third round the cylinder: it connects at bottom with a pipe *e*; at its two upper ends it opens into two large chambers *f g*, extending near the whole length of the cylinder, and closed by covers, *h h*, screwed on; *i k* are square openings (shown by dotted squares in fig. 280,) in the cylinder communicating with the chambers *l m*; in *f g* are two valves closing the ends of the curved passage *d*, and preventing any water returning down the passage *d*; *n o* are two passages from the top of the cylinder to convey away the water; they come out in the top of the cylinder, which, together with the top of the chambers *f g*, form a flat surface, and are covered by two valves, *p q*, to retain the water which has passed through them. A chamber, K, is screwed over these valves, and has the air-vessel *k*, figs. 278 and 279, screwed into its top; from each side of the chamber, a pipe, *w w*, proceeds, to which a hose is screwed, as shown in fig. 280. Levers, *x x*, are fixed to the spindle at each end, as shown in fig. 279, and carry the handles H H, by which men work the engine. When the piston moves, as shown by the arrow in fig. 281, it produces a vacuum in the chamber *f*, and that part of the cylinder contiguous to it, the water in the pipe *e* then opens the valve *m*, and fills the cylinder.

The same motion forces the water contained in the other part of the cylinder through the valve *q*, into the chamber K, and thence to the hose through the pipe *w*; the piston being turned the other way reverses the operation with respect to the valves, though it continues the same in itself. The pipe *e* is screwed by a flanch to an upright pipe P, fig. 282, connected with another square iron pipe, fastened along the bottom of the chest of the engine; a curved brass tube, G, comes from this pipe through the end of the chest, and is cut into a screw to fit on the suction-hose when it can be used; at other times a close cap is screwed on, and another brass cap at H, within the chest, is screwed upwards on its socket to open several small holes in it, and allow the water to enter into the pipe; in this case the engine-chest must be kept full of water by buckets. The valves are made of brass; and turn upon hinges. The principal advantage of the engine is the facility with which it is cleared from any sand, gravel, or other obstructions, which a fire-engine will always gather when at work.

The chambers *f g*, being so large, allow sufficient room to lodge a greater quantity of dirt than is likely to be accumulated in the use of the engine at any one fire, and if any of it accidentally falls into the cylinder, it is gently lifted out again into the chambers, by the piston, without being any obstruction to its motion; to clear the engine from the dirt, two circular plates of five inches diameter, are unscrewed from the lids *k k* of the chambers *f g*, and when cleaned are screwed on again; these screw-covers fit perfectly tight without leather, and can be taken out, the engine cleared, and enclosed again in a very short time, even when the engine is in use, if found necessary.

The two upper valves *p q*, and chamber K, can also be cleaned with equal ease, by screwing out the air-vessel *k k*, fig. 278, which opens an aperture, of five inches, and fits air-tight, without leather, when closed. The valve may be repaired through the same openings. The use of the air-vessel, *k k*, figs. 278 and 279, is to equalize the jet from the engine during the short intermittance of motion at the return of the piston-stroke; this it does by the elasticity of the compressed air within it, which forces the water out continually, though not supplied quite regularly from the engine.

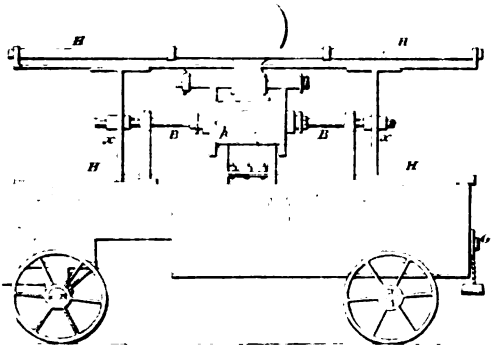
The engine from which the drawing was taken, was constructed for the Sun Fire Insurance Company, in London, and from some experiments made by their agent, Mr Samuel Hubert, appears to answer every purpose.

[Owing to the pecular organization of the fire department of this city, (Philadelphia,) which is supported solely by the zeal and public spirit of private volunteer associations, with but slender pecuniary assistance from the city authorities, great emulation and rivalry exists, and the attention of ingenious men attached to them, has been directed to the improvement of the fire apparatus, and their exertions have been attended with corresponding success. The introduction of riveted hose was perhaps the most important improvement in our means of extinguishing fires, and without it no apparatus should be considered effective. It is made of sole-leather dressed to an even thickness and breadth, lapped over and riveted with iron or copper tinned rivets, which are introduced from the under or inside of the leather, having a burr placed upon the point which is then riveted down, and closed with a hollow-set punch; the lengths of hose are joined together, by a double row of rivets diagonally. Fifty feet thus made form a section, having at each end a screw, (one male and the other female,) turning upon itself and forming a swivel. An indefinite number of sections may be attached by introducing one screw into the corresponding one without twisting the hose. The merit of introducing this important improvement belongs to The Philadelphia Hose Company of

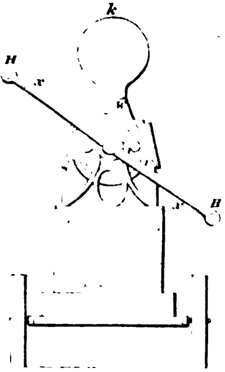
ROWNTREE'S FIRE ENGINE

From 278 to 283.

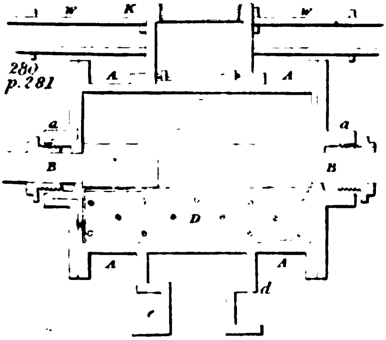
278. p. 281



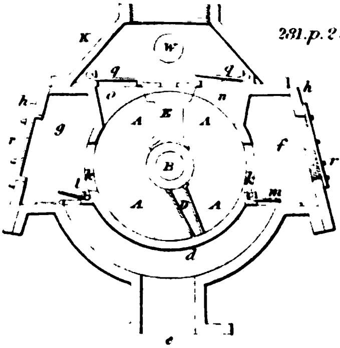
279. p. 281



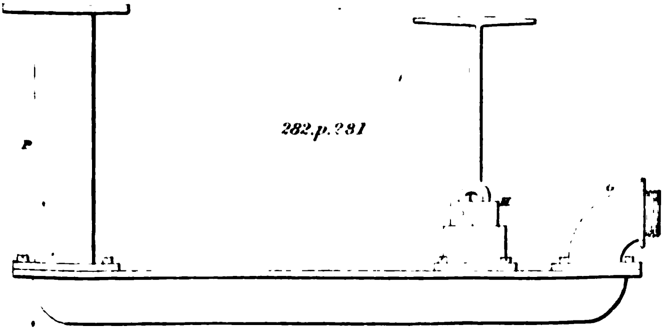
280. p. 281



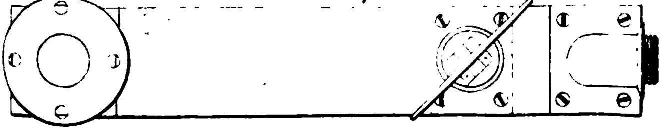
281. p. 281



282. p. 281



283. p. 281



this city, under whose direction and at whose expense the experiments were tried, which have resulted in its present state of perfection. The committee who executed the work were Messrs Sellers, Pennock, and Morris.

Many important improvements have also been made in the fire-engine, especially in the form and arrangement of the various parts, and in the perfection of the workmanship.

Plate No. 36*, Fig. 1. exhibits a side view of an engine in the form preferred and adopted by most of our firemen. The levers are of a shape introduced by Mr Perkins, and are by far the most convenient of any now known or in use. The handles hinge upon studs in the centre of the cross-bars, attached to the end levers, and when put in operation fall into clasps at the extremities, and are there firmly retained. The improvement in the form of the levers was first made by Mr Adam Eckfeldt.

Fig. 2. represents the working parts of the same engine. A A are the chambers or pumps, which are made of brass. The part in which the piston works is bored and polished; they are bolted down upon the seats M, which are in like manner secured to the bottom of the engine by bolts through the feet L L. The pistons B B are two metal disks, each enclosed in a cup, (pressed,) of leather, the bottoms of which come in contact with each other, and are firmly connected by the piston-rods *n n*. These rods work in a movable pin P, (the centre being permanent, and passing through the guide H,) are alternately raised and depressed by the motion of the lever K, (a portion of which is represented,) moving upon its centre G. When the piston is raised the chamber fills with water, forced into it by the pressure of the atmosphere on the surface, through the opening in the seat M. It is then depressed, the valve *e* closes, and the water passes up through the water-way *c* into the air vessel F, and is there retained by the closing of the valve *a*, until by the frequent and alternate operation of the pistons, the air in the air-vessel is so far condensed, that by its re-action it forces the water through the pipe O with considerable violence on any object towards which it may be directed.

This engine is on precisely the same principle as Newsham's, and differs only in the mechanical arrangement and structure, to which it is decidedly superior, being by far more simple.

Fig. 3. represents another variation of the fire-engine pump, the origin of which we are unacquainted with, but believe it to be French. It consists of a cylinder of brass A A, laid horizontally, the piston working in the same direction, the rod being attached to drops at right angles with the levers, which have the same form as those last described. When the piston is moved, the water follows by atmospheric pressure through the pipe, entering by the circular aperture J. On the return of the piston, the valve at P closes, and the water is forced through the water-way *o*, into the air-vessel K, its return being prevented by the closing of the valve *e*, it is discharged through hose leading from the pipe L. The same takes place alternately on moving the piston back and forward. The piston-rod B is a permanent rod of polished iron working through the stuffing-box Q, attached to the cap *n*; *m* and *n* are cast-iron caps fitted to the ends of the chamber, and are rendered air-tight by leather or leaden joints, securely connected together by bolts passing the length of the chamber with a nut on each end. This description of works has some objections. It is, however, advantageously used in machines called hydraulions, which are a combination of a hose-carriage and engine in one. It is compact, and can therefore be arranged so as to carry a large quantity of hose in the body, without making it too unwieldy. On the other hand, it is very liable to get out of repair, and difficult to put in order; in fact, to perform this operation, the whole works must come out. Again, owing to its position, all dirt and gravel that finds its way into it, naturally settles to the lower side, and wears that part away before any other, very soon making the chamber oval, and of course not perfectly water-tight. It is, however, well adapted to suctions, as the chamber being constantly full of water on both sides of the piston-head, no air can pass to destroy the effect.

Fig. 4. is a suction tube, on a new and improved construction, and is an admirable substitute for the leathern suction hose formerly used, possessing all its advantages without its defects. It is formed of copper tubes *e, e, e*, five feet long, connected at each end by joints B, moving upon themselves, (thereby making the whole tube flexible,) called swivel joints. The pipe is here represented folded up in the form as carried on the engine, and may be extended at pleasure by unfolding the joints to the length of 17 or 18 feet. C is the female screw which attaches it to the outside of the engine, (which is penetrated,) and forces it against a leather collar within the aperture J in the suction-seat attached to the horizontal chamber, fig. 3. D, fig. 4, is a bulb of copper pierced with holes, which let the water pass, and exclude all dirt and other matter which would be injurious to the works of the engine.

Fig. 5. is a sectional view of Perkins's single-chamber engine. A is the working chamber of copper or brass, having small holes *d, d*, near the top, through which the water passes. B is a division cylinder between the chamber and air-vessel, and is firmly secured at the top, while the lower end terminates within three inches of the bottom of the chamber, and is intended to form the inner coat of the air vessel. The whole is surrounded by a cylinder *c*, which forms the outer coat of the air vessel, and is connected at both ends with the chamber by a plate of solder ¾ths of an inch thick, into which they are firmly incorporated. The whole stands upon a seat of brass, having an opening through which the water passes, and is closed by the valve F. The chamber is firmly bolted to the bottom of the engine by bolts passing through the cap G with nuts. K is the plunger of copper, (drawn,) the capacity of which is half that of the chamber; it works through a stuffing-box *o o*, made perfectly tight by bolts secured in the caps. J is the piston-rod, movable on the joint at M, which gives a perpendicular motion to the plunger. L is the piston head through which is passed the cross-bar of the levers, which are similar to those first described. The operation of this engine is different from any other in use or known by us, and was, we believe, a new idea of Mr Perkins. Suppose the plunger or piston raised, water flows through the valve F by atmospheric pressure, and the whole capacity of the chamber below the plunger is filled. It is then depressed. The lower valve F closes, and those in the box *s s*, attached to the plunger, open. The plunger, we have already noticed, is exactly one-half the size or area of the chamber; consequently, when the plunger is depressed, one-half the water which passes through the valve *s s* remains in the space between the chamber and plunger; the other half passes through the small holes *d d*, down the space between the chamber and division B, and thence through the discharge pipe N. When the plunger is raised again, the upper valve closes, the water which remained passes out through the same openings as before, and the chamber below the box is again filled; the same operation is repeated at every stroke of the levers; thus a continued stream is sustained with one chamber, the water being projected both at the up and down stroke.

The only recommendation which can be given to this engine over the double chamber is, that while the same effects

FIRE ENGINE.
Merrick & Towne
Makers

Fig. 1.
p 283

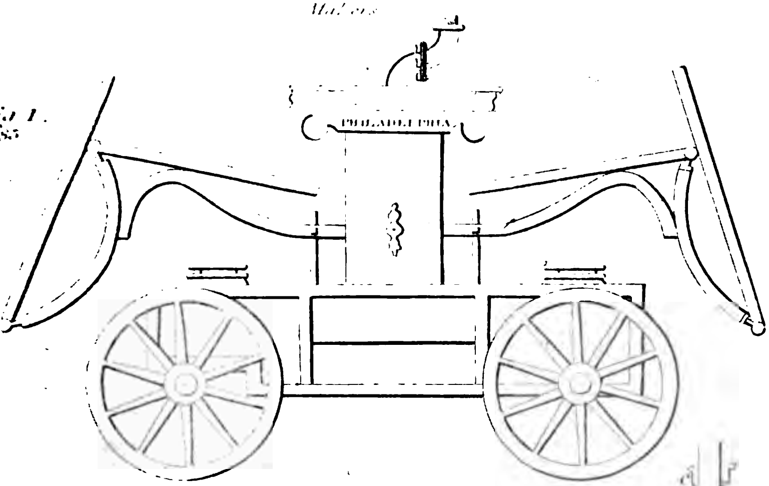


Fig. 2. p 283

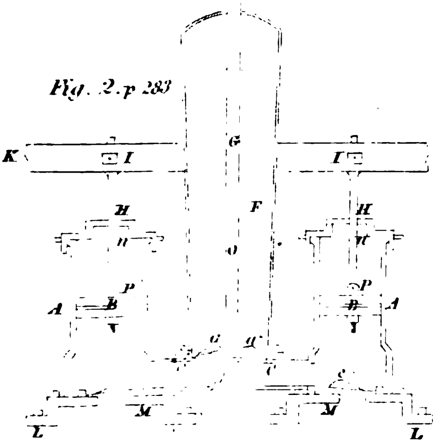


Fig. 4.
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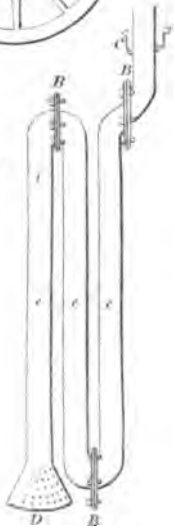

Fig. 3.
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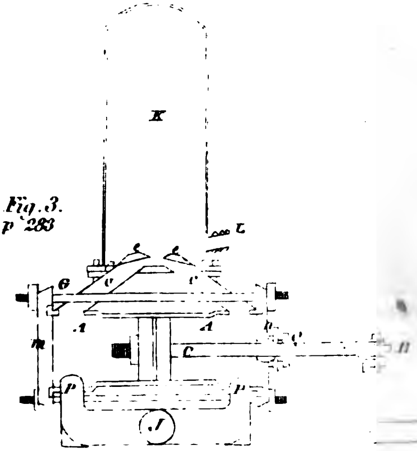

Fig. 5.
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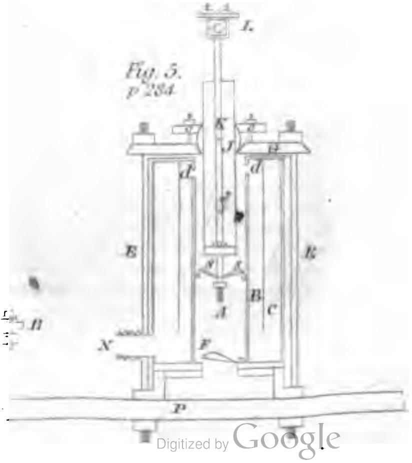


are produced, the expense of the machine is decreased 20 per cent. But no form of engine is so simple, durable, or easily repaired, as those represented in figures 1 and 2.

The principles on which the air-vessel operates, are so ably explained in the description of Newsham's engine, that it is almost unnecessary to allude to them. There is, however, no power gained by the use of this instrument; the only advantage obtained by it is that the reaction of the condensed air serves to keep up a constant pressure on the water in the air-vessel, and sustains the stream perfect at the moment of the return stroke. The table showing the distance to which air of several degrees of condensation will project water, (which closes the article alluded to,) may be very true in theory, but is not found to be so in practice, because the resistance of the atmosphere increases in a greater ratio than the velocity of the water; and beyond a certain distance it is probable the water cannot be projected, as it is found the resistance becomes so great as to disperse and separate the stream into small particles when projected with great velocity.]

JACKS.

The jacks which we propose here to describe are simple machines used for raising heavy weights.

Fig. 341 represents the common or simple hand jack; a block of wood about two feet six inches long, 10 inches broad, and six inches wide, is perforated with a square hole or mortise through it lengthwise for the reception of an iron rack B. This rack is formed with a double claw or horn at its upper end. A small pinion C is made to engage in the teeth of the rack. The axis of the pinion is supported in iron plates bolted to each side of the block, and one end of the axis projects through the side plate, with a square to receive a winch or handle, which, being turned round, the pinion elevates the rack B in the mortise, and raises the claw or horns up to the load to which it is applied. To prevent the weight of the load running the pinion back, the handle is detained by a hook or link *a*, fastened to the outside of the block.

When a greater power is required than the simple rack and pinion are capable of exerting, a combination of wheel-work is used, as shown in the same figure, where A A is the block of wood, which in this case is made sufficiently wide to contain the cog-wheel F, fixed to the pinion C, which acts in the teeth of the rack B. G is a second pinion of four leaves, working in the wheel F; and the axis of this pinion projects through the side of the block for the winch H to be fixed on it. The block A A is made in two halves, and the recess for the wheel F, and the pinion G, is cut in one of the halves; the other, being laid flat against it, supports the front pivots of the wheel and pinions. The two halves are bound together by strong iron hoops *b b*, driven over the outside. The rack has a claw N, at its lower end, projecting out sideways through an opening or slit cut through in the front half of the block. This claw can be introduced beneath a stone which lies nearly flat upon the ground, and which consequently could not be acted upon by the claw on the top of the rack. To prevent the rack descending when it has a load upon it, the small click *a* drops into its teeth, but clears it in going up; when it is not required to detain the rack, this click can be turned out of the way sideways.

Fig. 243 is a screw jack. The block of wood A A is perforated nearly its whole length with a hole sufficiently large to allow the screw B to move up and down without touching. The screw passes through a nut *n*, fixed into the top of the block A; and if the screw is turned round, it must rise up through the nut, and elevate the claw F. This claw is fitted on the top of the screw with a round collar, which allows the screw to turn round without turning the claw: and the claw N, which projects through a groove or opening made in the side of the block, is fitted to the screw with a smaller collar. The bottom of the block has four short points to prevent the machine slipping when used upon hard ground. To give motion to the screw, the lower half of it is formed into a square, and a worm-wheel C is fitted upon the square. The teeth of this wheel are engaged by a worm on the axis of the winch H, and plates of iron, *a b*, are bolted on each side of the block, near the middle of its height, to carry the ends of the axis of the winch and of the worm which is concealed by the worm-wheel C. When the winch is turned round, it causes the wheel C to revolve by the action of the worm in its teeth; and as the wheel is fitted on the square part of the screw, it compels it to turn with it, but at the same time allows the screw to move up and down.

Jacks have been also constructed upon the hydrostatic principle discovered by Pascal, and which has been applied to practice by the late Mr Bramah, in this and various other useful machines.

CRANES.

Cranes are certain simple machines in which either the wheel and axle, or wheel and pinion are introduced, to effect the raising of heavy loads, such as the loading or unloading of shipping at the quays or wharfs, or the raising or lowering goods to and from chambers or warehouses.

Various modes have been adopted to turn the wheel, or that part of the machine which is applied to the same purpose, by introducing long staves into the axle, by which it acquires the name of a capstan, or windlass; or by a rope passing over the wheel, and putting it and the axle in motion by friction. Other methods have been adopted, such as forming the wheel hollow, and causing it to revolve by means of labourers inside of it, walking up its sides, which consequently descends beneath their weight; or by forming it into a platform, lying in a slanting direction, and the labourers pushing against a fixed arm, which forces the platform or wheel round under their feet.

Most of the cranes constructed with the wheel and axle occupy too much space, which is of importance, and consequently, where cranes are in general use, have been superseded by the wheel and pinion, which is of a more compact and convenient construction. The wheel and pinion is generally accompanied with a ratchet-wheel and pall, or some other method of locking the handle, so that should the labourer desist from his exertion, the load may not return to the place whence it has been raised.

The frame-work, or that part of the crane which does not immediately operate to raise the load, is divided into three parts, the post, the jib, and the stay. The post is the upright piece, almost universally made to turn on a centre; the jib is the arm extending from the upper part of the post, and in some cases is horizontal, but more frequently at an angle to the horizon; and the stay is that piece which supports the jib, reaching from the lower part of the post to nearly the extremity of the jib.

The most simple form of the crane is that commonly used in stone and timber wharfs for unloading vessels, for which purpose it is well adapted, its power being very great. It has a frame consisting of a strong beam supported horizontally at 10 or 12 feet from the ground, on the top of several vertical posts very firmly fixed in the ground, and securely braced with stays in every direction. At the extremity of the horizontal beam the upper part of the jib is supported, the lower pivot resting on a post in the ground. The jib, or gibbet, as it is called, from a resemblance to that machine, is a triangular frame of wood, one side being perpendicular, and supported on pivots at the top and bottom, so that the whole moves round on these as a vertical axis of motion. Near the upper end of the perpendicular post, a beam proceeds, forming the upper side of a triangle, while the third side is a brace, extended from the foot of the perpendicular, to support the upper piece. From the extremity of the latter, the burden is suspended by a rope passing over a pulley; the other end of the rope is coiled round a vertical roller, or capstan, turning on pivots, one supported by the horizontal beam first mentioned, and the other on a post in the ground. The capstan is turned round by means of long horizontal levers fixed to it, at which a great number of men may be employed to push them round, or in some cases they are drawn by horses. As the levers admit of a very great length in proportion to the diameter of the windlass on which the rope coils, the power of this simple crane is very considerable, and may be doubled by a pair of blocks or pullies at the jib. When the burden is raised to a sufficient height, by turning the capstan, the jib, being swung round on its pivots, will convey the load into a cart or wagon placed on shore by the side of the crane.

Another kind of crane, which is equally common with the above, but used for lighter burdens, has the same jib, as indeed most cranes have; but the windlass, or barrel for the rope, is placed horizontally, and has a large vertical wheel fixed upon it. This is made of two wheels fixed on an axis at a distance apart, and united by boards, so as to form a large hollow cylinder or drum. Several men get into this wheel, and by constantly walking upwards on the inside, give it a tendency to revolve, and wind up the rope on the barrel. It is surprising, that so imperfect, this should have been so universally adopted as it was, till within these few years. Even when the wheel is sixteen feet in diameter, the labourers within cannot walk so far up it, from the perpendicular, as to have any effective leverage to turn it round; though they are always exposed to danger, and frequently meet with most shocking and fatal accidents, from slipping down in the wheel, or from being overpowered by the load; in this case, the wheel runs back with an accelerating velocity, and the people are thrown about it in a most dreadful manner. From these defects of the common construction, skilful mechanicians have devised cranes that are not only more safe, but more powerful in their operation, than the common walking-crane. Some of the best of these will be described in the present article.

Mr Padmore, many years ago, contrived to prevent the danger attending the use of the construction last described, by putting a ring of cogs all round the outside of the great wheel, and applying a trundle provided with winches to turn it. By this addition, the power was increased in proportion to the number of cogs in the wheel to the number of staves in the trundle; and in order to prevent the wheel from running back by the force of the weight, should the man within it slip, or leave off walking, he added a ratchet-wheel to the end of the trundle. Two winches being fixed to the ends of the axis of the trundle, gave the people attending the crane the means of assisting the man in the wheel, when the load rendered it necessary. On the axis of the trundle is likewise fixed a wooden wheel provided with a brake or gripe, which could be forcibly pressed on the circumference of the wheel by a lever, to cause such a friction as would prevent the weight from descending too rapidly. By this means, heavy goods may be raised or let down at pleasure, without any danger of injuring the men in the crane. This contrivance is ingenious; but the rapid motion of the circumference of the large walking-wheels, in most cases, rendered it inapplicable, unless a smaller cog-wheel was fixed upon the same axis with the walking-wheel.

A crane to be turned by winches, was contrived by the late Mr Ferguson, which has three trundles, with different numbers of staves. Any one of these may be applied to the cogs of a horizontal wheel, mounted on an upright axle, round which is coiled the rope for drawing the weight. This wheel has 96 cogs; the largest trundle 24 staves, the next 12, and the smallest six; so that the largest revolves four times for one revolution of the wheel, the next eight, and the smallest sixteen. The winch is occasionally fixed on the axis of either of these trundles for turning it, and is applied to one or the other, according as the weight to be raised is smaller or larger. There is also a fourth trundle acting in the teeth of the great wheel, and on its axis is a brake and ratchet-wheel. While the load is drawing up, the teeth of the ratchet-wheel slip round below a catch which falls into them, and prevents the crane from turning backward, thus detaining the weight in any part of its ascent, if the man who works at the winch should accidentally quit his hold, or wish to rest himself before the weight is completely raised. Making a due allowance for friction, a man may raise, by such a crane, from three to twelve times as much in weight as would balance his effort at the winch, viz. from 90 to 360 lbs. taking the average labour.

Many other constructions of wheel-work are in common use for cranes. When they are turned by a winch, it is proper to apply a fly-wheel to the axis of it, both to equalize the efforts of the labourer who turns it, and in case he accidentally lets go the handle, to prevent the load from running down so quickly as to endanger any thing. It is convenient to have several different powers to a crane of this kind, to adapt it for the different burdens to be raised; this is best done by employing a train of several wheels, each turned by a pinion smaller than itself. Thus, suppose the barrel on which the rope or chain winds to be 12 inches in diameter, and has a cog-wheel of 96 teeth fixed on the end of it; this is turned by a pinion of 12 leaves; on the same axis with this is a wheel of 32 teeth, moved by a pinion of eight, actuated on a third axis, which should carry the fly-wheel. A winch of one foot radius can be applied to any of these three axes in the crane, and will give three different powers. Thus, if it is applied to the gudgeon of the barrel, it will double the power of the balance, because the winch describes a circle which is twice as large as the barrel on which the chain winds; if the winch is fixed on the end of the axis which carries the pinion of 12, and the wheel of 32, it will give the labourer a purchase of 16 times; and lastly, when the winch is applied to the pinion of eight, his efforts will be multiplied 64 times. This simple mechanism is rendered very complete by fixing a fly-wheel upon the axis of the pinion of eight, to prevent all accidents; for which purpose it is more effective than a ratchet-wheel, and requires no attention. The spindles of all the pinions are made capable of sliding endwise, for the purpose of disengaging the wheels from each other at pleasure, that when the wheels are not employed, there may be no unnecessary friction in turning them round.

The gibbet of a crane is a very principal member, as we have before explained; but in its common construction, it has some defects. The rope by which the burden is raised passes exactly over the gudgeon of the vertical beam of the jib, and is confined between two small vertical rollers, in order that it may always lead fair with the pulley or sheave at the extremity of the jib. According to this construction, whenever the jib turns round its axis, the rope is bent so as to form an angle more or less acute, which causes a great increase of friction, and produces a continual effort to bring the arm of the jib into a parallel position to the inner part of the ropes. These inconveniences may appear to be trifling, but, in actual practice, they are of no small importance; for they necessarily require a much greater degree of power in raising goods, and the application of a constant force to keep the jib in the position that may be requisite; while the partial stress which is exerted on only a few strands of the rope, whilst bent into an acute angle, destroys it in a very short time.

A simple construction of the jib, invented by Mr Bramah, obviates all these defects, and at the same time possesses the very desirable property of permitting the jib, of what is termed a wharf or landing crane, to revolve wholly round its axis, and to land goods at any point of the circle described by the arm of the jib.

The simplest form of this contrivance is shown in fig. 343, in which A A represents the jib of a warehouse-crane projecting from a wall. It has, as usual, a pulley at the extremity, from which the goods are suspended. The improvement consists in placing a pulley at S, to conduct the rope down through the axis of motion of the jib, the collars or rings *a a*, on which it swings, being perforated for the purpose. The rope afterwards passes under a pulley *b*, which conducts it into the house to the crane or machine by which the weight is elevated. The pulley *b* may be placed between the collars *a a*, and then there will be no necessity for a perforation of the lower pivot of the jib. When the jib is required to describe a complete circle, instead of the two brackets at *a a*, fixed to the wall, a cast-iron pillar is used to support the jib, the collars *a a* fitting upon it; the pillar is hollow, to admit the rope through it, and is firmly fixed in a vertical position, by a plate cast on the lower end of it, and screwed down on the timber of the wharf. Beneath these beams there is another pulley, in place of *b*, to conduct the rope to the crane.

Fig. 344 represents a crane mounted on four trucks, to be capable of removal from place to place. It was employed on Ramsgate-pier, for lifting stones used in the building, and is extremely well adapted for such a situation, as it requires no fixture, and will take up a weight of four tons with four men, which is sufficient power for such purposes. It was designed and executed by Mr Peter Kier, by order of the trustees for the management of the harbour at Ramsgate. Its base consists of a cast-iron frame marked A B, nine feet seven inches square, and two tons weight, supported on four cast-iron wheels *b b*, one pair of which is fixed on a common axle, which moves round on a centre fixed to one side of the frame. This axle has an arm projecting across beneath the frame to the opposite side, where a rack, or segment of a wheel, is fixed on it, as shown at *c*, engaging a pinion *r*, shown before the rack, on the top of whose axis a winch is applied at *d*. Now, by turning this pinion, it twists the wheels round upon the centre, to steer the crane when moving from place to place. A vertical cast-iron shaft marked D F, weighing 23 cwt. is erected on the centre of the iron frame, and is supported by oak braces E E, stepped into boxes cast out of the iron frame A B, at its angles, so as to form a very strong perpendicular column, round which axis the whole crane traverses. The weight of the framing and wheel-work is supported by a steel pivot, or gudgeon, on the top of the shaft F, and is guided by a collar embracing the shaft at I. The framing of the jib, or movable part of the crane, consists of a long beam G H, bearing the pulley G at the extremity, resting on the pivot of the upright pillar in the middle, and the other end supporting the frame for the wheel-work L M N; into this beam are framed two uprights Q Q, suspending the platform I K, on which men who work the crane stand. It is braced by a diagonal stay J P; and a cross piece R, to prevent its bending.

Mr Bramah's ingenious hydrostatic principle of gaining a great power is applicable in several ways to the raising of heavy weights, and has been frequently employed in powerful cranes. In these the power is not obtained by wheel-work, pullies, or any other ordinary mechanical powers, but on the principle of the experiment called the hydrostatic paradox, which has been known for ages; but the application of its powers to useful purposes is due to Mr Bramah.

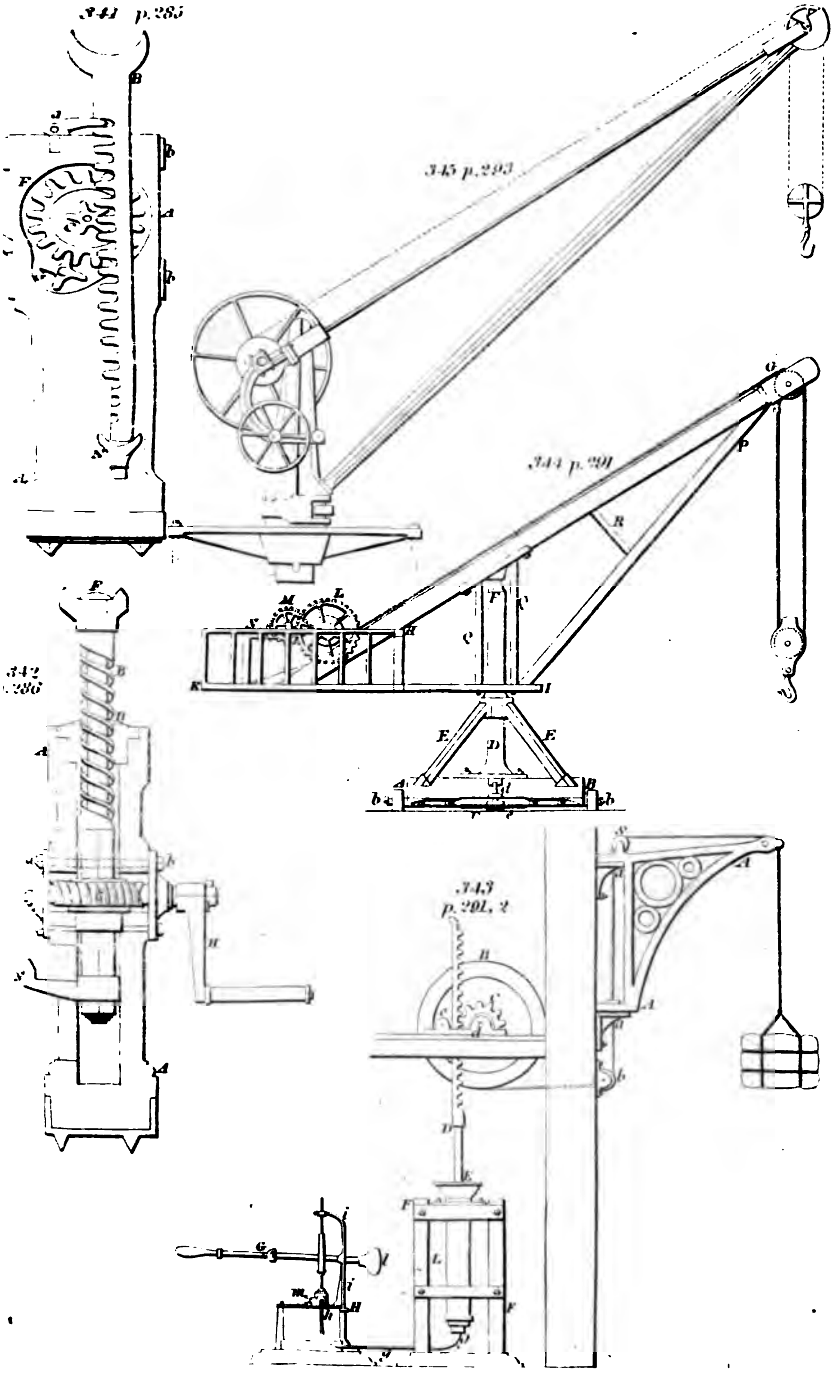
The simplest form is, for a machine to raise a heavy weight to a small height. A metallic cylinder, sufficiently strong, and bored truly cylindrical within, has a solid piston fitted into it, which is made perfectly water-tight, by leather packing round its edge, or other means used in hydraulic engines. The bottom of the cylinder must be made sufficiently strong with the other parts of the surface, to resist the greatest strain which can ever be applied to it. In the bottom of the cylinder is inserted the end of the small tube, the aperture of which communicates with the inside of the cylinder, and introduces water or fluids into it; the other end of the pipe communicates with a small forcing-pump, by which the water can be injected into the cylinder beneath its piston; the pump has of course valves to prevent the return of the water. Now, suppose the diameter of the cylinder to be six inches, and the diameter of the piston of the small pump, or injector, only one-quarter of an inch; the proportions between the two surfaces or ends of the said pistons will be as the squares of their diameters, which are as 1 to 24; therefore the areas will be as 1 to 576; and supposing the intermediate space between them to be filled with water, or any other dense and imcompressible fluid, any force applied to the small piston will operate on the other in the above proportion of 1 to 576. Suppose the small piston, or injector, to be forced down, when in the act of forcing or injecting, with a weight of 20 cwt. which can easily be done by means of a long lever, the piston of the great cylinder would then be moved up with a force equal to 1 ton multiplied by 576.

Fig. 343 represents a crane constructed upon the *hydrostatical* principle, that is, by the injection of water from a small pump into a large cylinder, which is fitted with a piston, having a rack attached to it for the purpose of turning a pinion upon the axis of a large drum-wheel or barrel, round which the rope is coiled, and from thence passes to the jib.

The figure A A represents the jib, made of iron, and supported upon two brackets *a a*, projecting from the wall of the warehouse in which the crane is supposed to be erected. The rope passes over the pulley S, and down through holes in the brackets *a a*, then turns under the pulley *b*, and comes to the lower side of the great drum-wheel B. The pinion C is fixed on the same axis with this, and its gudgeons turn in small iron frames *d*, bolted down to the floor of the warehouse. The pinion C is actuated by the teeth of the rack D, and a small roller, whose pivot is shown at *e*, presses against the back of the rack, to keep its teeth up to the pinion. The rack is attached to the piston D of the cylinder L, in which the power for working the crane is obtained. The piston passes through a tight collar of leather on the top of the cylinder at E, which does not admit of any leakage by the side of it, and therefore if any water is forced into the cylinder it must protrude the piston from it. The cylinder is supported in a wooden frame F F, and has a

JACKS & CRANES

From 341 to 345



small copper pipe *g g*, proceeding from the lower end of it, communicating with a small forcing-pump at *h*; this stands in an iron cistern H, which contains the water, and sustains the standard *i i*, for the centre of the handle G, with which the pump is worked by one or two men. The upper extremity of the standard *i i* guides the piston rod of the pump, to confine it to a vertical motion; *l* is a weight for counterbalancing the handle G of the pump. From what we have said before, the operation of this machine is evident; the power of the cylinder D is in proportion to its size compared with the size of the pump; but as it only acts through short limits, the pinion and drum B are necessary to raise the weight a sufficient height. The operation of lowering goods by this crane is extremely simple, as it is only necessary to open a cock at *m*, which suffers the water to escape from the cylinder into the cistern H, and the weight descends, but under the most perfect command of the person who regulates the opening of the cock; for by diminishing the aperture, he can increase the resistance at pleasure, or stop it altogether.

Fig. 345 is a side elevation of a crane. The post is immovable, and is fixed on an iron frame, with arms extending in the form of a cross, the extremities of which are bolted down by strong screws to large blocks of stone sufficiently heavy to more than counterpoise the weight to be raised by the crane. In the top of the post is fixed a wrought-iron pivot, by which the weight is supported; and a strong cast-iron cap bears on the pivot, and has attached to it two iron frames, one on each side, that receive the pressure from the stay, as well as support the pull of the jib, which is formed of two bars of wrought-iron; the lateral pressure is borne by the bottom of the post, round which two friction-rollers turn to facilitate its motion. This crane will carry five tons with safety.

PRESSES.

The press is a machine in most extensive use in the mechanic arts. It is usually made of wood, or iron, and serves to squeeze or compress any body very close.

Screw-presses generally consist of six members, or pieces; viz. two flat smooth tables of wood or metal, between which the substance to be pressed is placed; two screws, or worms, fastened to the lower plank, and passing through two holes in the upper; and two nuts, in form of an S, serving to drive the upper plank, which is movable, against the lower, which is stable and without motion,

Presses used for expressing liquors, are of various kinds; some, in most respects, the same as the common presses, excepting that the under plank is perforated with a great number of holes, to let the juice run through into a tub or receiver underneath.

1. An improved *cider-press*, turned by a windlass, is shown in fig. 284.

A A is the base or foundation with its supporting parts; B B the cheeks or sisters; D D the cross-piece at top, through which the screw passes, and which consequently contains the female screw; E the screw with its appendages; F F the bridge or cross-piece which acts on the pommage; G G is the wide plank or vat on which the pulp rests in the hair bags, in which the mode of the liquor's passing off is seen.

This kind of press may be advantageously employed for packing cloth, paper, and other goods; as also in paper-mills, for flattening and rendering paper solid, and in the manufacture of woolen cloth, for glazing and setting a finish upon the article in its last stage.

2. Two elevations of a very good *screw-press* for a *paper-mill* are given in figs. 285 and 286.

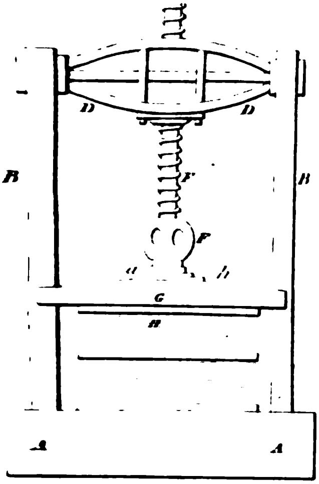
A A is the bed formed of an immense beam of oak; and each of the cheeks, B, consists of a long iron bar, *b b*, fig. 286, the ends of which are welded together, so that it forms a long sink, one end of which receives the end of the bed A, and the other the end of a massive cast-iron bar D, through which the screw E is received, and its nut fixed fast therein. The open spaces of the long links or cheeks, *b*, *b*, are filled up by rails of wood C, which support the weight of parts of the press when it is not in action, but these beat nothing when the press has any articles under pressure in it; these articles are laid at H, on the bed, and the follower, G, is pressed upon them by the screw, when it is turned by a long lever put through the holes in the screw-head F.

The screws employed for paper-presses are generally formed with such coarse threads, and so rapid a spiral, that the elasticity of the paper is sufficient to force it to run back. To these a ratchet-wheel, *a*, is fixed, and a click *e*, fig. 287, is applied to its teeth: to prevent its return, the click is supported on a bar *b d*, which moves on a centre at B, but the other end is retained by a catch or lever *f g*. When the press is to be relieved, the

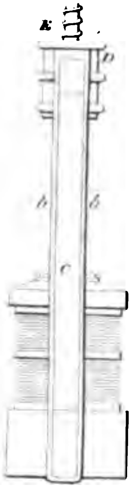
PRESSES.

From 284 to 292

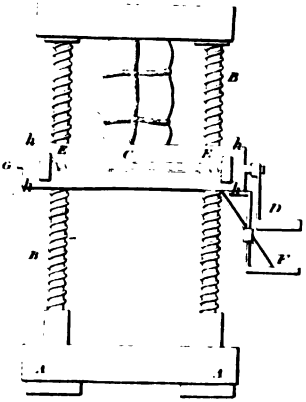
285 p 291

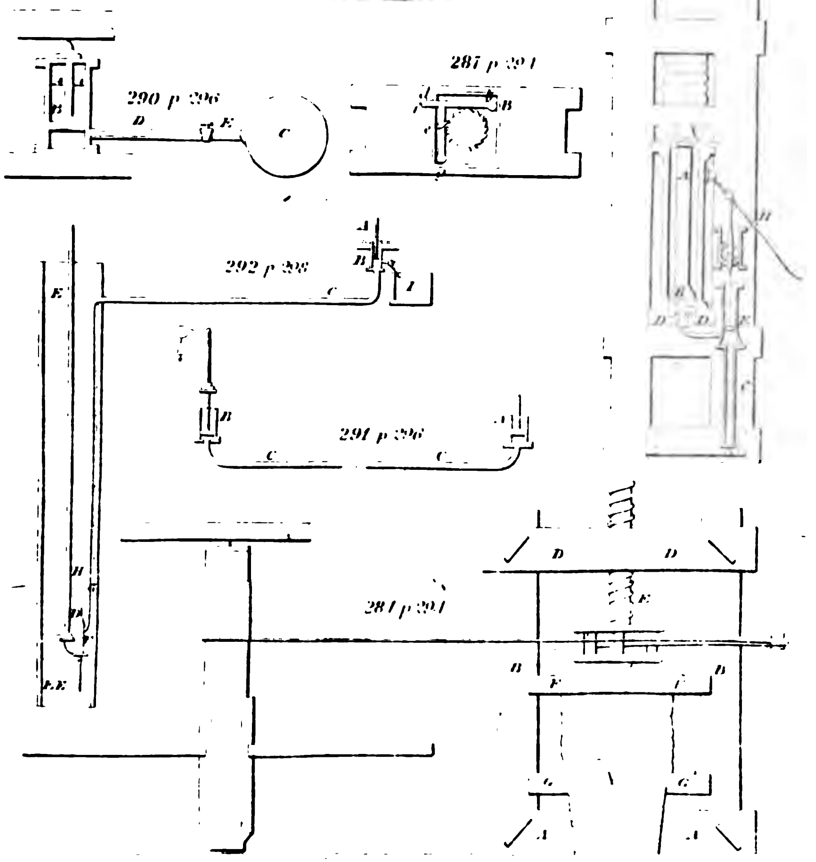


286 p 291



288 p 295





end *f*, of the catch, is driven back; this relieves the bar *d b*, and the click no longer detaining the ratchet-wheel, the screw runs back.

3. A very ingenious and useful *packing-press* has been invented by Mr John Peek. It is represented in fig. 288.

A A, the frame of the press; B B, the large screws, which, in this press, contrary to those in common use, is fixed and immovable; C a circular iron bar, extending beyond the sides of the press, and having thereon two worms, or endless screws E E, which work in two toothed wheels fixed to the nuts, and, by turning the winch D, drive the nuts and bed up and down the screws as may be found necessary; F, a stage, suspended from the bed, and on which the men stand who work the press; such a stage may, if found necessary, be fixed at the other end of the bar, as shown by the square shoulder G. The bed of this press must be formed of two pieces of strong wood, which are held together by screws and nuts, passed through them, as shown at *h h h h*. The great utility of this press consists in its being capable of packing two sets of bales at once; thus answering the purpose of two presses, with more expedition.

4. The *hydrostatic* or *water-press*, or as it is sometimes called *Bramah's Press*, has, for a great number of purposes, superseded the use of the screw-press, over which it possesses great advantages, in all cases where a strong pressure is required. It is one among the many useful inventions of the late Mr Joseph Bramah, of Piccadilly; and is ingeniously contrived for applying the *quaqua versum* pressure of fluids as a powerful agent in many kinds of machinery.

These contrivances consist in the application of water, or other dense fluids, to various engines, so as, in some instances, to cause them to act with immense force; in others, to communicate the motion and powers of one part of a machine to some other part of the same machine; and, lastly, to communicate the motion and force of one machine to another, where their local situations preclude the application of all other methods of connection.

The first and most material part of this invention will be clearly understood by an inspection of fig. 289, where A is a cylinder of iron, or other materials, sufficiently strong, and bored perfectly smooth and cylindrical; into which is fitted the piston B, which must be made perfectly water-tight, by leather or other materials, as used in pump-making. The bottom of the cylinder must also be made sufficiently strong with the other part of the surface, to be capable of resisting the greatest force or strain that may at any time be required. In the bottom of the cylinder is inserted the end of the tube C; the aperture of which communicates with the inside of the cylinder, under the piston B, where it is shut with the small valve D, the same as the suction-pipe of a common pump. The other end of the tube C communicates with the small forcing-pump or injector E, by means of which water or other dense fluids can be forced or injected into the cylinder A, under the piston B. Now, suppose the diameter of the cylinder A be 12 inches, and the diameter of the piston of the small pump or injector E only one quarter of an inch, the proportion between the two surfaces or ends of the said piston will be as 1 to 2304; and supposing the intermediate space between them to be filled with water or other dense fluid capable of sufficient resistance, the force of one piston will act on the other just in the above proportion, viz. as 1 is to 2304. Suppose the small piston in the injector to be forced down when in the act of pumping or injecting water into the cylinder A, with the power of 20 cwt. which could easily be done by the lever H; the piston B would then be moved up with a force equal to 20 cwt. multiplied by 2304.

Thus is constructed a hydro-mechanical engine, whereby a weight amounting to 2304 tons can be raised by a simple lever, through equal space, in much less time than could be done by any apparatus constructed on the known principles of mechanics; and it may be proper to observe, that the effect of all other mechanical combinations is counteracted by an accumulated complication of parts, which renders them incapable of being usefully extended beyond a certain degree; but in machines acted upon or constructed on this principle every difficulty of this kind is obviated; and their power subject to no finite restraint. To prove this, it will be only necessary to remark, that the force of any machine acting upon this principle can be increased *ad infinitum*, either by extending the proportion between the diameter of the cylinder A, or by applying greater power to the lever H.

Fig. 290 represents the section of an engine, by which very wonderful effects may be produced instantaneouly by means of compressed air. A A is a cylinder with the piston B fitting air-tight, in the same manner as described in fig. 289. C is a globular vessel made of copper, iron, or other strong materials, capable of resisting immense force, similar to those of air-guns; D is a strong tube of small bore, in which is the stop-cock E. One of the ends of this tube communicates with the cylinder under the piston B, and the other with the globe C. Now, suppose the cylinder A to be the same diameter as that in fig. 289, and the tube D equal to one-quarter of an inch diameter, which is the same as the injector, fig. 289; then, suppose that air is injected into the globe C, (by the common method,) till it presses against the cock E with a fore equal to 20 cwt. which can easily be done; the consequence will be, that when the cock E is opened, the piston B will be moved in the cylinder A A with a power of force equal to 2304 tons; and it it obvious, as in the case fig. 289, that any other unlimited degree of force may be acquired by machines or engines thus constructed.

Fig 291 is a section, merely to show how the power and motion of one machine may, by means of fluids, be transferred or communicated to another, let their distance and local situation be what they may. A and B are two small tubes, smooth and cylindrical, in the inside of each of which is a piston, made water and air tight, as in figs. 288 and 289. C C is a tube conveyed under ground, or otherwise, from the bottom of one cylinder to the other, to form a communication between them, notwithstanding their distance be never so great, this tube being filled with water or other fluid, until it touch the bottom of the piston; then, by depressing the piston A, the piston B will be raised. The same effect will be produced *vice versâ*; thus bells may be rung, wheels turned, or other machinery put invisibly in motion, by a power being applied to either.

Fig. 292 is a section showing another instance of communicating the action and force of one machine to another; and how water may be raised out of wells of any depth, and at any distance from the place where the operating power is applied. A is a cylinder of any required dimensions, in which is the working piston B, as in the foregoing examples; into the bottom of this cylinder is inserted the tube C, which may be of less bore than the cylinder A. This tube is continued, in any required direction, down to the pump cylinder D, supposed to be fixed in the deep well E E, and forms a junction therewith above the piston F; which piston has a rod G, working through the stuffing-box, as is usual in the common pump. To this rod G is connected, over a pulley or otherwise, a weight H, sufficient to overbalance the weight of water in the tube C, and to raise the piston F, when the piston B is lifted; thus, suppose the piston B is drawn up by its rod, there will be a vacuum made in the pump cylinder D, below the piston F; the vacuum will be filled with water through the suction-pipe, by the pressure of the atmosphere, as in all pumps fixed in air. The return of the piston B, by being pressed downwards in the cylinder A, will make a stroke of the piston in the pump cylinder D, which may be repeated in the usual way by the motion of the piston B, and the action of the water in the tube C. The rod G of the piston F, and the weight H, are not necessary in wells of a depth where the atmosphere will overbalance the water in the suction of the pump cylinder D, and that in the tube C. The small tube and cock in the cistern I, are for the purpose of charging the tube C.

By these means it is obvious that the most commodious machines, of prodigious power, and susceptible of the greatest strength, may readily be formed. If the same multiplication of power be attempted by toothed wheels, pinions, and racks, it is scarcely possible to give strength enough to the teeth of the racks, and the machine becomes very cumbersome and of great expense. But Mr Bramah's machine may be made to possess great strength in very small compass. It only requires very accurate execution. Mr Bramah, however, was greatly mistaken when he published it as the discovery of a new mechanic power. The principle on which it depends has been well known for nearly two centuries; and it is matter of surprise that it has never before been applied to any useful practical purpose.

5. The *Stanhope printing-press* is delineated in figs. 293 and 294, being elevations, and fig 295, a plan.

A A is a massive frame of cast-iron formed in one piece; this is the body of the press, in the upper part of which a nut is fixed for the reception of the screw *b*, and its point operates upon the upper end of a slider *d*, which is fitted into a dove-tail groove formed between two vertical bars *e e*, of the frame. The slider has the platen D D firmly attached to the lower end of it; and being accurately fitted between the guides *e e*, the platen must rise and fall parallel to itself when the screw *b* is turned. The weight of the platen and the slider are counterbalanced by a heavy weight E, behind the press, which is suspended from the lever F, and this acts upon the slider to lift it up, and keep it always bearing against the point of the screw.

At G are two projecting pieces, cast all in one with the main frame, to support the carriage when the pull is made; to these the rails H are screwed, and placed truly horizontal, for the carriage I to run upon them, when it is carried under the press to receive the impression, or drawn out to remove the printed sheet. The carriage is moved by the rounce or handle K, with a spit and leather girts very similar to the wooden press. Upon the spit or axle, a wheel, L, is fixed, and round this leather belts are passed, one extending to the back of the carriage to draw it in, and two others, which pass round the wheel in an opposite direction, to draw it out.

By this means, when the handle is turned one way it draws out the carriage, and by reversing the motion it is carried in. There is likewise a check strap *f*, from the wheel down to the wooden base M, of the frames, and this limits the motion of the wheel, and consequently the excursion of the carriage.

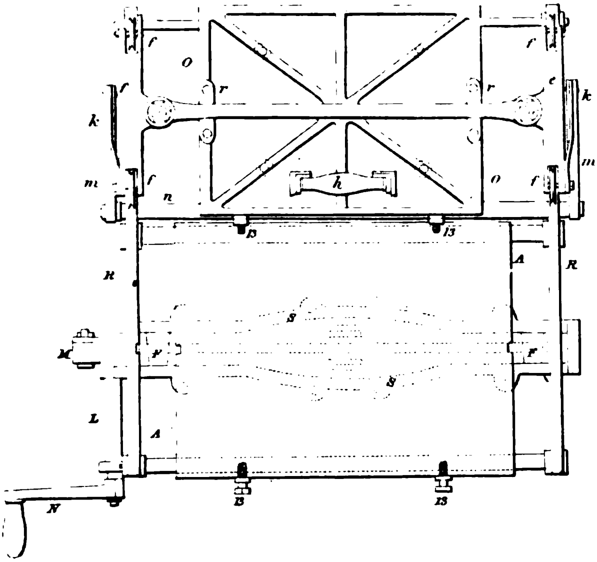
The principal improvement of Earl Stanhope's press consists in the manner of giving motion to the screw, *b*, of it, which is not done simply by a bar or lever attached to the screw, but by a second lever *e*, *g*; the screw, *b*, has a short lever, *g*, fixed upon the upper end of it, and this communicates by an iron bar, or link, *h*, to another lever, *i*, of rather shorter radius, which is fixed upon the upper end of the second spindle *l*, and to this the bar or handle, *k*, is fixed. Now when the workman pulls this handle, he turns round the spindle *l*, and by the connection of the rod, *h*, the screw, *b*, turns with it, and causes the platen to descend and produce the pressure. But it is not simply this alone, for the power of the lever, *k*, is transmitted to the screw, in a ratio proportioned to the effect required at the different parts of the pull; thus at first, when the pressman takes the bar K, it lies in a direction parallel to the frame, or across the press, and the short lever *i*, (being nearly perpendicular thereto,) is also nearly at right angles to the connecting rod *h*; but the lever, *g*, of the screw, makes a considerable angle with the rod, which therefore acts upon a shorter radius to turn the screw; because the real power exerted by any action upon a lever, is not to be considered as acting with the full length of the lever between its centres, but with the distance in a perpendicular drawn line, in which the action is applied to the centre of the lever. Therefore when the pressman first takes the handle K, the lever *i* acts with its full length upon a shorter length of leverage, *g*, on the screw, which will consequently be turned more rapidly than if the bar itself was attached to it; but on continuing the pull, the situation of the levers change, that of the screw, *g*, continually increasing its acting length, because it comes nearer to a perpendicular with the connecting rod, and at the same time the lever *i*, diminishing its acting length, because, by the obliquity of the lever, the rod, *h*, approaches the centre, and the perpendicular distance diminishes; the bar or handle also comes to a more favourable position for the man to pull, because he draws nearly at right angles to its length.

All these causes combined have the best effect in producing an immense pressure, without loss of time; because in the first instance the lever acts with an increased motion upon the screw, and brings the platen down very quickly upon the

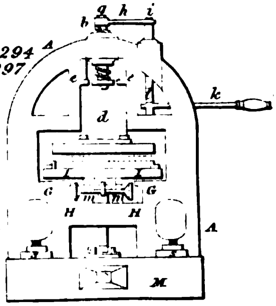
STANHOPE PRINTING PRESS, &c.

From 293 to 299. Pl.36*

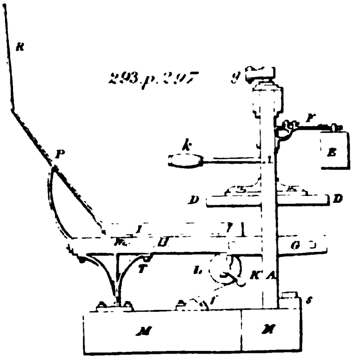
299.p.302



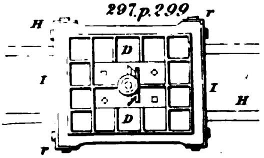
294 p.297



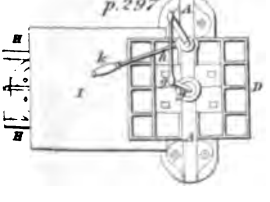
293.p.297



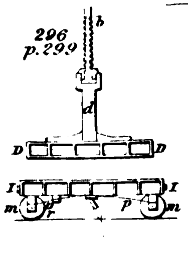
297.p.299



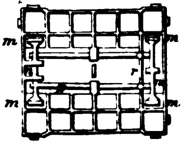
295 p.297



296 p.299



298.p.299



paper, but by that time the levers have assumed such a position as to exert a more powerful action upon each other, and this action continues to increase as the bar is drawn forwards, until the lever, *i*, and the connecting rod are brought nearly into a straight line, and then the power is immensely great, and capable of producing any requisite pressure which the parts of the press will sustain without yielding. The handle is sometimes made to come to rest against a stop, which prevents it moving further, and therefore regulates the degree of pressure given upon the work: but to give the means of increasing or diminishing this pressure, for different kinds of work, the stop is made movable to a small extent. A better plan is adopted by some makers of the Stanhope press, viz. to have a screw adjustment at the end of the connecting rod *h*, by which it can be shortened; it is done by fitting the centre pin which unites it to the lever *g*, in a bearing piece, which slides in a groove formed in the rod, and is regulated by the screw. This shortening of the connecting rod produces a greater or less descent of the platen, when the handle is brought to the stop.

The carriage of the press is represented with wheels, *m m*, beneath, to take off the friction of moving upon the ribs H. These wheels are shown at fig. 296, which is a section of the screw and the platen, with the carriage beneath it; and fig. 297 is a plan answering to it. Fig. 298 is a figure of a carriage inverted to show the wheels; then axles *n* are fitted to springs *p*, and these are adjustable by means of screws *r*, so that the carriage will be borne up to any required height. This is so regulated, that when the carriage is run into the press, its lower surface shall bear lightly upon the solid cheeks G, which are part of the body of the press, and these support it when the pressure is applied, the same as the winter of the old press; but the wheels by their springs act to bear up great part of the carriage with the types upon it, and diminish the friction, yet do not destroy the contact of the carriage upon the ribs, because this would not give the carriage that solidity of bearing which is requisite for resisting the pull. This is only at the time when the carriage is run into the press; because as it runs out, the ribs on which the wheels run rise higher, and therefore the wheels support the whole weight.

The manner in which the wheels run in rebates or recesses in the edges of the ribs, is shown at fig. 294. The carriage is made of cast-iron, in the form of a box, with several cross partitions, which are all cast in one piece, and though made of thin metal, are execeedingly strong; the upper surface is made truly flat, by turning it in a lathe. The same of the platen, which is likewise a shallow box; the slider *d* has a plate formed on the lower end of it, which is fixed by four screws upon the top of the platen, and thus they are united.

At the four angles of the carriage, pieces of iron, *r*, fig. 297, are screwed on, to form bearings for the quoins or wedges which are driven in to fasten the form of types upon it in the true position for printing. The tympan P, fig. 293, is attached to the carriage by hinges, with an iron bracket or stop to catch it when it is thrown back; the frisket, R, is joined to the tympan, and when opened out, rests against a frame suspended from the ceiling. The iron frame, A, of the press is screwed down upon the wooden base M, by bolts, which pass through feet, *s*, projecting from the lower parts of the iron frame. Another wooden beam is fixed into the former at right angles, so as to form a cross, which lies upon the floor. The ribs H, for the carriage to run upon, are supported from the wooden base by an iron bracket T.

The advantages of the iron presses in working are very considerable, both in saving labour and time. The first arises from the beautiful contrivance of the levers, the power of the press being almost incalculable at the moment of producing the impression; and this is not attended with a correspondent loss of time, as is the case in all other mechanical powers, because the power is only exerted at the moment of pressure, being before adapted to bring down the platen as quickly as possible. This great power of the press admits of a saving of time, by printing the whole sheet of paper at one pull, the platen being made sufficiently large for that purpose; whereas, in the press formerly used, the platen is only half of the size of the sheet. In the Stanhope press, the whole surface is printed at once, with far less power upon the handle than the old press, when printing but half the surface. This arises not only from the levers, but from the iron framing of the press, which will not admit of any yielding, as the wood always yields, and indeed is intended to do, the head being often packed up with elastic substances, such as pasteboard, or even cork. In this case much power is lost, for in an elastic press the pressure is gained by screwing or straining the parts up to a certain degree of tension, and the effort to return produces the pressure. Now, in this case, the handle will make a considerable effort to return, which, though it is in reality giving back to the workman a portion of the power he exerted on the press, is only an additional labour, as it obliges him to bear the strain a longer time than he otherwise would.

The iron presses have very little elasticity, and those who use them find it advantageous to diminish the thickness of the blankets in the tympan to one very thin piece of fine cloth; the lever has then very little tendency to return, and the pull is easy in the extreme, requiring very little more force to remove it at the latter than at the first part; indeed, the iron press is so different from the other press, that when an experienced pressman first tries it, he cannot feel any of that reaction which he has been accustomed to, and will not believe, till he sees the sheet, that he has produced any impression at all; and for many days after he begins to work at an iron press, he by habit throws back all the weight of his body in such a manner as to bring the handle up to its stop with a concussion that shakes his arm very much, and in consequence most pressmen, after a few hours' work, feel inclined to give up the iron press; but when they have once acquired a new habit of standing more upright, and applying only as much force as it requires, the labour of the pull becomes less than that of running the carriage in and out; and men who are accustomed to the iron presses only, would be scarcely able to go through the work of the old press.

Mr De la Haine has a patent for a Stanhope press, which answers extremely well; the only material alteration is, that he has substituted a spiral or curved inclined plane in place of the screw, which is fixed to the head of the press; and a cross-arm properly formed, and fixed on the upper end of the spindle, which, standing in place of the screw, acts against the fixed inclined plane. The action is very nearly the same as the screw, except that the surfaces admit of being made of hardened steel, and thus diminish the friction very much. The inventor of this for the common press was Mr Roworth; but Mr De la Haine has combined it with the levers and iron frame of the Stanhope press.

A common press, of great simplicity, and possessing the same advantage in point of power as Lord Stanhope gains by the compound levers, has been produced by Mr Medhurst, of Denmark-street, Soho.

6. In November 1813, Mr John Ruthven, of Edinburgh, took out a patent for an improvement in the printing-press, which differs from those heretofore used in the following particulars:

First, The types, plates, blocks, or other surfaces from which the impression is to be taken, instead of being situated upon a running carriage, as was formerly the practice, are placed upon a stationary platform or tablet, which is provided with the usual apparatus known to printers by the names of tympan and frisket, with points, &c. to receive the sheet of paper and convey it to its proper situation on the types after they had been inked.

Secondly, The machinery by which the power for the pressure is produced, is situated immediately beneath this platform or tablet; and the platen or surface which is opposed to the face of the types, to press the sheet of paper against them, can be brought over the types, and connected at two opposite sides or ends with the machinery beneath the tablet; by this machinery it is so forcibly pressed or drawn down upon the paper which lays upon the types, as to give the impression; which being thus made, the platen can be disunited from the machinery and removed from off the types by the foot, or otherwise, to take out the paper, and introduce a fresh sheet.

Thirdly, the said machinery for producing the pressure is a combination of levers, actuated by a crank, or short lever, turned by a winch, or handle, to which the pressman applies by his hand; or the pressure may be produced by the tread of the foot.

Fig. 299 is a horizontal plane; fig. 300, a vertical section taken through the middle; and fig. 301, an end view; the same letters of reference being used in each.

A A represent the tablet or surface upon which the types, &c. are laid, its surface truly flat, and may be made of wood, stone, or metal, or any other substance used for the carriage of printing-presses. This tablet is mounted upon a frame of wood or metal, consisting of legs B B, and cross braces C C, or any other kind of support may be used which will firmly sustain the tablet at a proper height from the ground. The tablet has a tympan, 8 and 9, joined to it at the end, 9, in the usual manner, and open into the position of the dotted lines 10, to take off or put on the sheet of paper, which is confined by the frisket, 11, in the usual manner; the dotted lines, 12, represent the gallows or support for the tympan and frisket when opened.

For fastening the types upon the tablet, or what the printers call making register, quoins or wedges may be introduced at the angles, in the usual manner; but a preferable method is to have screws 13, 13, fitted through pieces which are made fast to the sides of the tablet, and between the points of these screws the chase, or frame of types, is held steady upon the tablet, and may be adjusted.

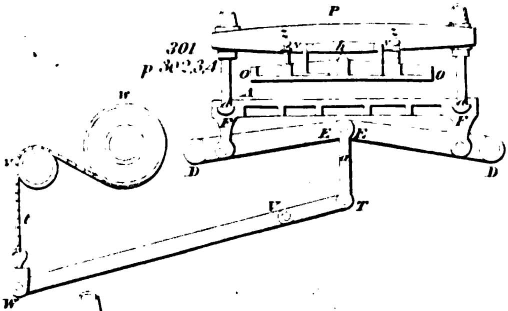
Beneath the tablet are the levers marked DE, D E, their fulcrums, or fixed centre-pins, being at D, and they act upon double hooks or clutches, F F. When the ends E are depressed by means of the third lever I G, situated beneath and common to both, the connection being made with the link *a*, the fulcrum of the lever is at G; and H is a third point to which the power to actuate it is applied by a connecting rod K, the opposite end of which is joined to a crank or short lever L M, situated upon an axis or spindle L, which extends to the front of the machine, and has a winch or handle N, fig. 299, upon it, for the pressman to turn it by.

The platen of the press is shown at O O; it may be made of wood or iron, as usual, but must be exactly true on the lower surface, which applies to the face of the types *b b*, upon the tablet A A. On the top of the platen is a strong metal bar P, which may be either cast in one piece with it, or united to it by screws at *r r;* at its extremities it has bolts *d d*, fixed to it by screws or otherwise; and at their lower ends they must have heads which are exactly fitted to the clutches or double hooks F F, before described. By means of these the platen is connected with the lever D E, D E, so that a pressure may be produced when the handle N is turned in the direction shown by the arrow in fig. 300. This, by turning the lever M about upon its centre L, pushes the rod K, which acting upon the point H of the lever G H I, moves it upon its centre G, and depresses the point I, which being connected with the extremities E of the levers D E, by the

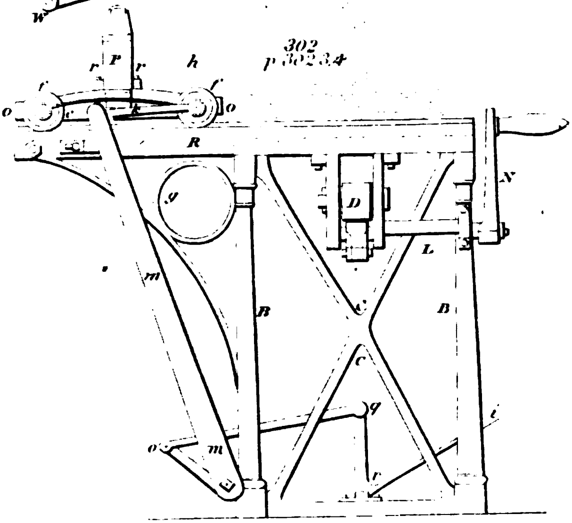
RUTHVEN'S PRINTING PRESS.

from 300 to 302.

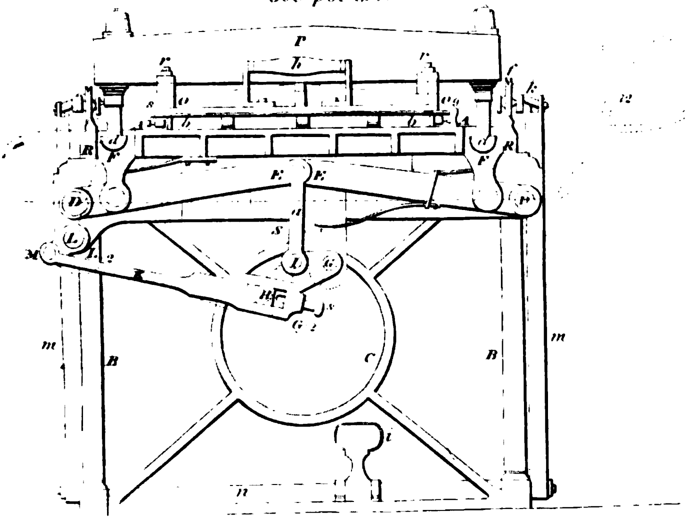
301 p 302.3.4



302 p 302.3.4



300 p 302.3.4



link *a*, they are made to partake of its motion, and draw down the platen upon the types by the clutches F F, and hooks *d d*. By returning the winch N to its original position, the pressure is relieved; and the platen may be removed from the types thus:—At the end of the bar P, two springs, *e e*, figs. 299 and 301, are fixed, and in the ends of these rollers or wheels, marked *f*, are fitted to revolve freely upon their centre-pins. These wheels, having grooves in their edges, run upon sharp angles, formed upon the upper edge of the two rails R R, which are extended across the frame of the press, and project sufficiently behind, as in figs. 299 and 301, being supported by brackets *g*, of fig. 301, if necessary. Upon these bars and wheels, (or sliders may be used instead of wheels,) the platen will run freely, to remove it backwards and forwards off the types, but when brought over them the bolts *d d* will enter the clutches F F, ready to receive the action of the levers, and give the pressure upon the tympan.

The springs *e* are so adjusted, that when the platen runs backwards or forwards upon the rails R, the under surface of it will be sufficiently raised above the tympan to run clear of it; but when the hooks *d d* and F F are united, and the pressure given by turning the handle N, these springs yield, though they have sufficient strength to raise up the platen clear of the tympan, the instant the pressure is relieved.

To draw the platen forward over the types, a handle *h*, is fixed upon it, for the pressman to take hold by; but it may be brought by the foot in the following manner: the two foremost wheels *f f*, have links, *k k*, jointed to their centre-pins, to connect them with the upper ends of the two long levers *m m*, which are fixed to one common axis *n*, fig. 300, extending across the whole machine, near the ground; upon the axis a short lever, *o*, fig. 301, is fixed, and a rod *q* unites it to the end of the bent lever *r i*, the arm *i* of which is made broad, to serve as a paddle for the foot; by depressing this, the arm *r* draws the short lever *o*, and the long lever *m m* causes the platen to advance truly parallel, and come up to the clutches F F.

To make all the work compact, the centres D D of the great levers, and of the lower lever G, as well as the pivots L of the winch N, are all supported in one frame composed of two metal cheeks S S, which are situated beneath the table, and united thereto by screws, or otherwise, as shown by the dotted line in the plan, fig. 299.

The power of the press will depend upon the proportion of the different levers, and the relation between the space described by the motion of the handle N, and the descent of the platen O; but it should be observed, that the power of this press increases as the handle descends to the horizontal position shown in fig. 300; first, because the handle is then in the most favourable position to receive the workman's body; secondly, the lever L M comes to a position which gives it a great power to force the rod K; viz. as is shown by the dotted line L 2, for when the lever and rod come to one straight line, its power to force the rod K may be considered as infinitely great; thirdly, the lever G H is in the most favourable position, marked G 2, to receive the action of the rod K, viz. perpendicular to it; fourthly, the lever G I is in a position to have greater power on the links *a* and the levers D E, than when it is in a horizontal position. All these sources combined have the best effect in saving time, and at the same time producing immense pressure; for when the pressure first takes hold of the handle N, it acts but with little advantage with respect to power on the levers, and therefore brings the platen down very quickly upon the tympans, with little loss of time or motion, till they have assumed positions in which they exert more powerful action upon each other, as above stated: and this action continues to increase until the lever L M and rod K come nearly into a line, when the power is immensely great, and capable of producing any required pressure, which the parts of the press will withstand without yielding. The handle N is made to come to a stop, or rest, which prevents its moving farther than the position of the dotted lines, and therefore regulates the degree of pressure given upon the work. But to give the means of increasing or diminishing the pressure at pleasure for different kinds of work, the centre hole of the pin H is made in a piece, which is fitted in a groove in the rod K; therefore by sliding it in the groove, it has the same effect of lengthening the rod, which produces a greater descent of the platen when the handle is brought to a stop; a screw, *s*, is fitted into the end of the groove, to screw the packing tight in the groove, and prevent it getting loose in working.

Another method of producing the same effect is to adjust the nuts which are fitted on the screws at the top of the bolts *d d;* or it may be done by loosening the screws at *r*, and fitting packing between the fitting of the platen and the bar P; the same may be done to adjust the platen parallel, if it prints more at one part than another.

Springs may be applied to take off all shake or looseness in the joints; it may be done in different ways: a strong spring may be fixed beneath the tablet, and act upon the clutch F, to lift it up, and keep the joint tight; or one small spring may be fixed on the lever D E, (as shown on the opposite side,) to lift the clutch F, and another being fixed to the lever beneath, and resting at the end upon a pin in the frame, will lift up the lever and link *a*, to keep them all tight for working. If it be thought objectionable for the rod K to push endways on the levers, it may be contrived to draw or pull, by placing the lever M above the spindle L, instead of beneath it, and also reversing the form of the lever G H I; the points G and H to remain as they are, but the point I to be on the opposite side of the centre, viz. above it; and with this alteration the drawing of the rod K will produce the pressure, instead of pushing it, as in the figure.

Fig. 302 shows another arrangement of the lever for a press. In this figure the same letters are used to denote the same parts; thus: A is the tablet, D E the levers, F the clutches, O the platen, P the cross-bar; the ends E of the levers are connected by a link *a*, with a third lever T W, whose centre or fulcrum is at V; the power is applied to the long end by a chain *t*, which is conducted over a pulley or roller *v*, and wound upon a wheel *w*, which is fixed upon the axle of the handle to work the press. To give greater power, the wheel may be formed like a spiral, instead of circular, that the chain may lay upon a shorter radius when the pressure is produced.

From the first invention of printing, till within a very few years, the printing press remained unchanged; and it is truly surprising, that so long a period as four centuries should have rolled away, without a single improvement in so important a machine.

The printing press of Lord Stanhope, ingenious and beautiful as it is, should rather be considered as an improvement than as an invention. This press being made of cast iron, having the surfaces of the table and platen turned true, and a compound lever added to the screw, is more solid and compact, and produces a better impression, with less manual exertion, than the common wooden press, with a stone table and wooden platen; but still the parts are the same, and the only difference consists in producing better workmanship with better materials.

No improvement of importance was therefore made till after the year 1790, when Mr William Nicholson, the editor of the Philosophical Magazine, obtained a patent for a machine, for printing on *paper*, *linen*, *cotton*, *woollen*, and other articles, in a more neat, cheap, and accurate method, than by the printing presses then in use.

This method consisted, first, in making his moulds, punches, and matrices, for casting letters, in the same manner, and with the same materials, as other letter-founders, with the exception that, instead of leaving a space in the mould for the stem of one letter only, he left spaces for two, three, or more letters, to be cast at one pouring of the metal; and at the lower extremity of each of those spaces (which communicate by a common groove or top) he placed a matrix, or piece of copper, with the letter punched upon its face in the usual way. He then brought the stems of his letters to a due form and finish, not only by rubbing it upon a stone, and scraping it when arranged in the finishing-stick, but likewise by scraping it, on one or more sides, in a finishing-stick whose hollowed part was less deep at the inner than the outer side. That side of the groove which was nearest the face of the disposed letter, he called the outer side; and the purpose accomplished by this method of scraping was, that of rendering the tail of the letter gradually smaller the more remote it was, or farther from the face. Such letters as these could be firmly imposed upon a cylindrical surface, in the same manner as common letters are imposed upon a flat stone.

Secondly, he applied the ink, or colouring matter to the types, forms, or plates, by causing the surface of a cylinder, smeared or wetted with the colouring matter, to roll over the surfaces of the said forms or plates; or by causing the forms or plates to apply themselves successively to the surface of the cylinder. The surface of this colouring cylinder was covered with leather, or with linen, woollen, or cotton cloth. When the colour to be used was thin, as in calico-printing, he proposed that the covering should be supported by a firm elastic stuffing, consisting of hair, or wool, or woollen-cloth, wrapped one or more folds round the cylinder. When the covering was of woollen-cloth, it was to be defended by leather, or oil-skin, to prevent its imbibing too much colour, and by that means losing its elasticity. It was absolutely necessary that the colouring matter should be evenly distributed over the surface of the cylinder; and for this purpose, when the colour was thick and stiff, as in letter-press printing, he applied two, three, or more small cylinders, called distributing rollers, longitudinally against the colouring cylinders, so that they might be turned by the motion of the latter. The effect of this application was, that every lump or mass of colour which was redundant, or irregularly placed upon the face of the colouring cylinder, was pressed, spread, and partly taken up and carried by the small rollers to the other parts of the colouring cylinder; thereby preserving an even face of colour. When the colouring matter was thinner, he did not apply more than one or two of these distributing rollers; and when very thin, he applied an even blunt-edge of metal, or wood, or a straight brush, or both of these last against the colouring cylinder, for the purpose of rendering its colour uniform. When he applied colour to an engraved plate, or cylinder, or through the interstices of a perforated pattern, as in the manufacturing of some kinds of paper-hangings, he used a cylinder entirely covered with hair or bristles in the manner of a brush.

And thirdly, he performed all his impressions, even in letter-press printing, by the action of a cylinder or cylindrical surface.

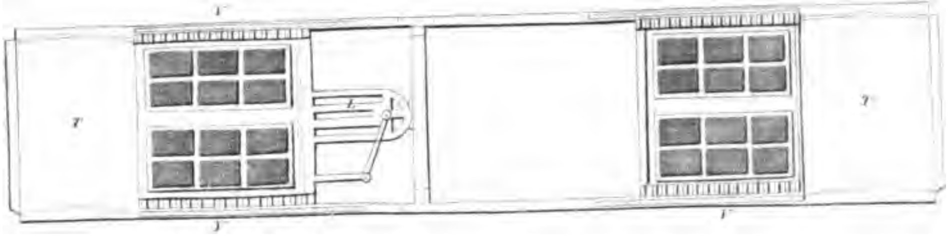
Though Mr Nicholson did not carry his ideas into successful practice, he may deservedly be considered the father of modern improvements in this important art. With him originated the idea of inking types by means of rollers, and of producing impressions by means of cylinders, which constitute the essential parts of all modern printing machines.

The honour of being the first to carry these ideas into successful practice is due to Mr Koënig, by birth a Saxon, who, after various attempts to improve the common press, and which resulted, to use his own words, "in discovering that they were only employing a horse to do what had been before done by a man," succeeded in producing a machine in which the impression is given by a cylinder. This machine was erected at the office of the Times newspaper, and two on a similar principle were erected at Mr Bensley's printing office, and although some publications have stated that the latter were destroyed by fire, in 1819, they continue to be worked at the present day. These errors may have arisen from the great difference in the appearance of

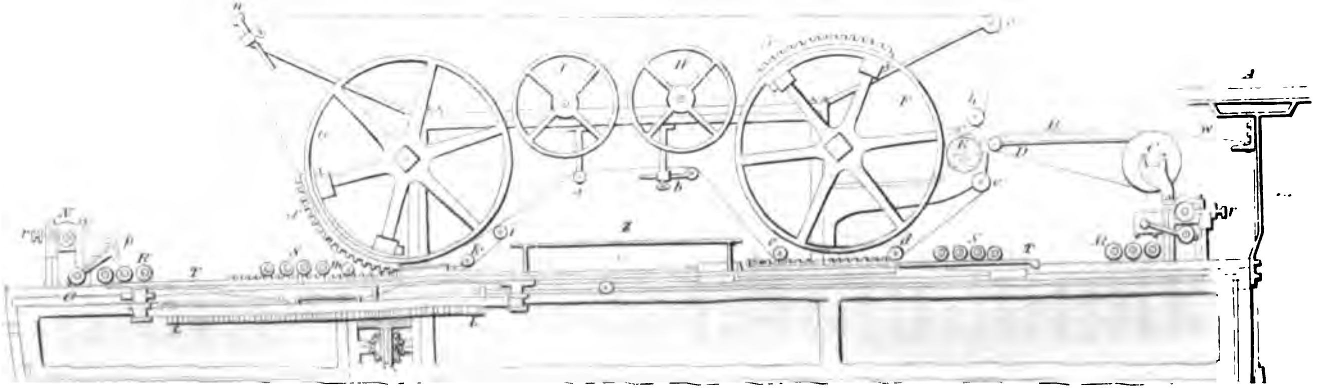
APPLEGATH & COWPER'S PRINTING MACHINE

Plate 38.—Fig. 304 & 305.—Page 307

305



304



the machine now, and when first erected. This is owing to a reduction of the complexity of the inking apparatus, by Messrs Applegath and Cowper, who have produced a machine far superior to that by Mr Koënig, and which possesses nothing in common with it, but the pressing-cylinders, the inking-rollers, and the tapes to hold the sheet of paper on the cylinders. The pressing-cylinders and inking-rollers were first suggested by Mr Nicholson; and tapes are similarly used in machines for the ruling of paper for account-books. These gentlemen, therefore, though producing their machine subsequently to Mr Koënig, cannot, with justice, be accused of having in the slightest degree infringed upon his invention. Mr Koënig's machine possessed originally *sixty* wheels; Messrs Applegath's and Cowper's but *sixteen;* and the machines of the former are now almost entirely superseded, even in the office of Mr Bensley, the principal proprietor of Koënig's patent, by the improved machines of Applegath and Cowper.

A perspective view of Messrs Applegath and Cowper's machine is represented by fig. 303, and a longitudinal section, to explain the manner in which the paper passes through to receive the impression upon both sides, and the mode of applying the ink to the surface of the types by fig. 304. Though in these figures, all the material motions of the machine are displayed, yet some of the minute parts, which produce the various movements, have been omitted, in consequence of the diminutive scale of the figures, which is only about one-third of an inch to a foot.

The supply of the blank paper is laid upon a support, or table, A, from whence the sheets are taken, one by one, by a boy, standing upon an elevated platform, who lays them out upon the table, B, which has a number of narrow linen tapes or girths passing across its surface. These tapes are formed into endless bands, which extend round the cylinders, or rollers, C and D, in such a manner, that when the rollers are turned round, the motion of the tapes will carry the sheet of paper along with them, and deliver it over the roller E, where it is seized between two systems of endless tapes, passing over a series of rollers to keep them extended. These endless tapes are so adapted, in number and position, as to fall between the pages of printing, and also on the outsides, or beyond the margin of the printing; they may, therefore, remain in contact with the sheet of paper on both sides during its whole passage through the machine; by which means, the paper being once received or taken in between the two systems of endless tapes, it will be capable of continuing its motion along with the tapes, in order to bring it into a situation to be printed on both sides, without destroying the register (or coincidence of the pages on the opposite side of the sheet.) F and G represent the two main cylinders which effect the pressure upon the paper. They are mounted upon strong axes, which turn in stationary bearings affixed to the main frame of the machine. H and I are two intermediate cylinders, situated upon axes between the main cylinders. Their use is to effect the inversion of the sheet of paper, in order to print the opposite side.

We must now describe the manner in which the two systems of endless tapes before mentioned are arranged, to give a clear idea of the operation of the machine. We will suppose one system of tapes to commence at the upper part of the roller E, from whence they proceed in contact with the under portion of the circumference of the main cylinder F; they then pass over the upper part of the intermediate cylinder H, and under the intermediate cylinder I, from whence they proceed to encompass a considerable portion of the main cylinder G; and by passing in contact with the rollers *a*, *b*, *c*, *d*, and *e*, they arrive again at the roller E, from whence they commenced, thereby forming one of the systems of endless tapes. The other system we will suppose to commence at the roller *h*. They are equal in their number to the tapes already described, and correspond with them also in their place upon the cylinders, so that the sheets of paper may be securely held between them. The second tapes descend from the roller *h* to the roller E, where they meet and coincide with the first system, in such a manner that the tapes proceed together under the main cylinder F, over the cylinder H, under the cylinder I, and round the main cylinder G, until they arrive at the roller *i*, where they separate; having remained thus far in actual contact, except at the places where the sheets of paper are held between them. From the roller *i*, the paper descends to the roller *k*, and by passing in contact with the rollers *m*, *n*, and *o*, they arrive at the roller *h*, from whence they commenced. Thus the two systems of the endless tapes are established and arranged so as to be capable of circulating continually, without interfering with each other.

The cylinders, P, G, H, and I, as also the roller E, are connected by toothed wheels, as represented in the perspective view, fig. 303, so as to cause their circumferences to move with one uniform velocity, and thereby prevent any sliding or shifting of the two systems of tapes over each other during their motion, as much of the perfection of the printing depends upon this circumstance. The separate forms of types for printing the two sides of the sheet are placed at a certain distance asunder, upon one long carriage, which is represented in a detached state at fig. 305. This carriage, with the forms of type secured upon it, is adapted to move backwards and forwards upon steady guides or supports attached to the main frame of the machine, in such a position that the surface of the types may be operated upon by the circumference of their respective cylinders F and G, to produce the impression as the carriage moves backwards and forwards. This reciprocating movement of the carriage is effected by a pinion fixed upon the end of a verticle spindle K, fig. 304, engaging in the teeth of an endless rack, L L, which is connected by a system of levers with the type carriage, in such manner that when the pinion is turned round, it engages as alternate periods in the teeth formed upon the opposite sides of the rack L L, and, consequently, on the opposite circumference of the pinion; thereby a continuous motion of the pinion communicates a reciprocating motion to the rack and carriage. The vertical spindle K is turned by a pair of bevelled wheels from the pinion P, fig. 303, which receives its motion by an intermediate wheel, Q, from the toothed wheel upon the end of the main cylinder G.

The mechanism for furnishing and distributing the ink upon the surfaces of the types in this machine, is very ingeniously arranged, and performs its operations with great certainty. It is one of the most important points, and the most difficult to effect in printing machines. Two similar and complete systems of inking apparatus, one situated at each end of the machine, are adapted to ink their respective forms of types; we will therefore describe, by references to fig. 304, the inking apparatus situated at the right hand end of the machine. It consists of a cylindrical metal roller, N, which has a slow rotatory motion communicated to it by a catgut band passing round a small pulley, upon the end of the axis of the main cylinder, G. The roller, N, is adapted to carry down a thin film of ink upon its circumference, by turning in contact with a mass of ink disposed upon a horizontal plate of metal, the edge of which plate is ground straight, and fixed by screws, *r*, *r*, at a small adjustable distance from the surface of the said roller. V represents an elastic composition roller, which is mounted upon a frame turning in an axis, *p*, extending across the main frame of the machine. This roller is connected by cranked-levers, with a small eccentric circle fixed upon the end of the axis of the cylinder G, (as seen in fig. 303), which causes it to move round the axis, *p*, and remain for a short period in contact with the surface of the ink roller N, (as seen by the position at the left hand end of the machine, fig. 304), thereby receiving a portion of ink upon its surface; it then descends and rests with its whole weight upon the surface of a flat metal plate or table, T, which is affixed to the type carriage, as seen in fig. 305; so that the reciprocating motion of the carriage causes the ink-table, T, to receive ink upon its surface from the elastic roller V. In this situation, when the type carriage returns, the surface of the table T is obliged to pass under three small elastic rollers seen at R, which are mounted upon pivots in a frame, with liberty of motion up and down, in order that the rollers may bear with their weight upon the surface of the table.

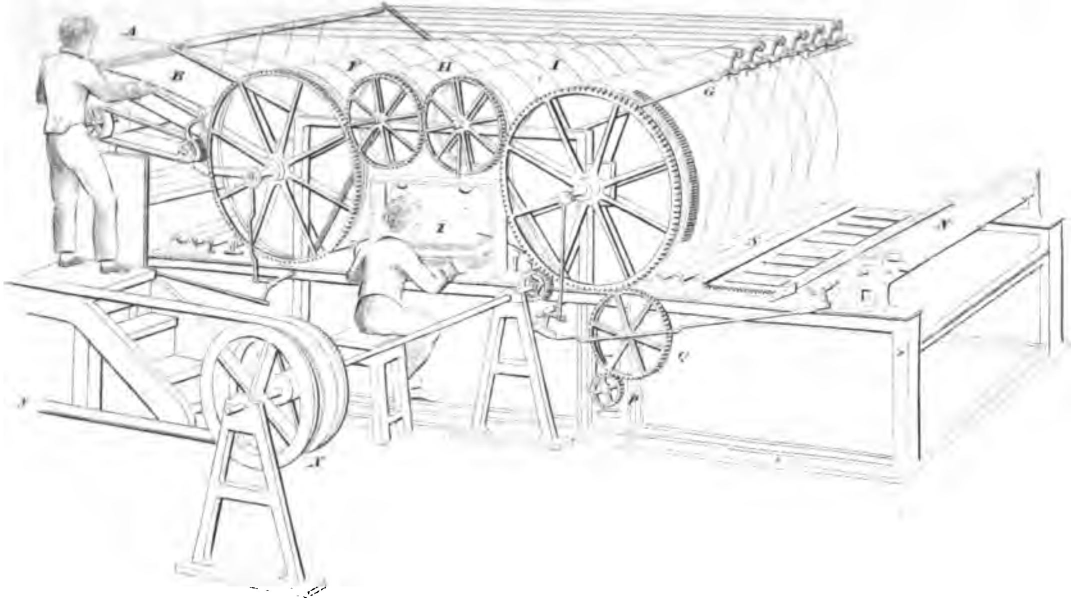
The frame in which they are centred has also a slight end motion given to it by the inclined form of the end of the table T (as seen in fig. 305), bearing against a roller fixed upon the said frame. Thus the small composition roller R, operates in a very complete manner to equalize the supply of ink over the surface of the table T, and by the farther motion of the type carriage, the ink-table is caused to pass under four small elastic rollers (seen at S), which, in like manner, bear with their weight upon the surface of the table (but without end motion), and thereby take up the ink upon their circumferences. The type carriage then returns, for the table T to receive a new supply of ink, and by the form of types passing under the elastic rollers, S, the letters become inked in a very perfect and uniform manner. Whilst the operation of inking the types is going on at one end of the machine, the printing is performed at the other end on one of the sides of the sheet from the types last inked, and *vice versa.* The type carriage is caused to move steadily along with the circumferences of the cylinders F and G, by having racks, *y y*, formed on each side of the forms of types (as seen in fig. 304), which engage with sectors, or portions of toothed wheels, *x x* upon the ends of the said cylinders; at which part the surfaces of the cylinders are covered with a blanket or felt, to give elasticity, and cause them to press equally upon the paper, as in ordinary printing presses.

The machine is put in motion by a strap, *y y*, passing

APPLEGATH & COWPER'S PRINTING MACHINE

Plate 39. — Page 311

303



round a pulley, X, as seen in fig. 303, upon the axis of which a pulley or pinion is fixed, engaging with the teeth of the large wheel upon the end of the main cylinder G. Thus the various cylinders, with their two systems of tapes, are caused to revolve with a uniform movement in the direction of the arrows (seen in fig. 304), whilst the type-carriage travels alternately backwards and forwards upon its guides, as before mentioned.

The operation of printing is performed as follows:—The sheets of blank paper are laid, one by one, upon the table B, so as to bear upon the linen tapes which extend over its surface. In this situation, the rollers C and D are caused to move a portion of a revolution, by the operation of a lever fixed upon the axis of the roller D, being acted upon by another lever fixed on the cog-wheel of the main cylinder, F. This motion advances the sheet of paper sufficiently to enable it to be seized between the two systems of endless tapes at the point where they meet each other, or between the rollers *h* and E. As soon as the sheet of paper is carried clear off the table B, the rollers C and D are caused to turn back again to their original position, by the operation of a weight, W, and a cord, *w*, as seen in fig. 304, ready to advance a second sheet of blank paper into the machine. The sheet of paper is carried along between the system of tapes, and applies itself to the circumference of the main cylinder, F, upon the blanket before mentioned; and by the continuous motion of the cylinder, the sheet of paper is pressed upon the surface of the form of types as they pass under the cylinder by the reciprocating motion of the carriage.

By this means, one of the sides of the sheet receives its impression at the same time that the form of types situated at the opposite end of the carriage is receiving the ink, as before described. Now, by the continuous motion of the machine, the sheet of paper advances in company with the endless tapes, round the intermediate cylinders, H and I, until it applies itself to the blanket upon the surface of the main cylinder G; at which place it will be found in an inverted position, so that the printed side of the sheet is in contact with the blanket, and the blank side of the sheet downwards, which, upon meeting with the other form of types at the proper instant, is pressed upon their surface sufficiently to produce the impression. Thus having arrived at the point *i*, where the two systems of tapes separate, the printed sheet is delivered upon the board Z, where it is received by a boy, and laid upon the pile.

Engravings of this machine have appeared in several periodical publications, and in the Supplement to the Encyclopædia Britannica, in all of which it is called "Bensley's Printing Machine." This is a mistake, as Applegath and Cowper are the original inventors and patentees of the identical machine from which those engravings were made. It must have been merely from the circumstance of its being in Mr Bensley's office that his name has been erroneously affixed to it.

With these machines are now printed, the Morning Chronicle, English Chronicle, St James's Chronicle, Whitehall Evening Post, Morning Herald, Examiner, Sunday Times, Bell's Messenger, and John Bull newspapers. The machine by which the Morning Herald is printed throws off 2400 newspapers per hour, printed on one side; which is the customary way of printing newspapers, in order to allow time for the other half of the paper to be composed.

[VERTICAL PRINTING-PRESS, INVENTED BY DANIEL NEALL, OF PHILADELPHIA.

8. From an examination of this press, we shall at once perceive its conformation and construction to be altogether new. While in operation, so regular and impulsive are its movements, that a spectator would readily conclude it to be automatical. The motion of the bed and type, which are easily elevated by the hand of the operator, gives motion to the whole establishment. The press seems to be performing its various parts by a kind of instinct, while the operator, abridged of his labour, and nearly superseded in his office, has but little left him to perform. In this point of view it may very properly be considered a labour-saving machine, and the advantages resulting from this fact are too obvious to escape the notice of an observer.

The art of printing, although affording abundant advantages to the world as the conservator of all other arts, has been unaccountably neglected, and has not until recently received that attention from scientific and literary genius which its merits undoubtedly claim. Printers themselves, though of all others more immediately concerned in the facility of improvements, have been contented to drudge on in the elaborate minutiæ of their profession, and the bulk of mankind, accustomed to printed books from their childhood, have grown up in the belief that an art so perfect in its adaptation and effects cannot admit of improvement.

But we have now to exhibit a press, (see plate 40*,) upon a principle entirely different from all others. This press is the invention of Daniel Neall, an ingenious mechanic of Philadelphia, and is secured to the inventor by letters patent of the United States, in November 1825.

It is called the vertical press from its perpendicular position while in the act of printing, and in contradistinction to the old establishments, which are horizontal.

The original plan adopted by the inventor at his first setting out has been completely established. He has applied the power of machinery so as to obviate the necessity of two men to work one press, by enabling one man or boy to perform with less exertion and fatigue, equal to two men upon any other press whatever.

The vertical press differs in form from all others. The platen A is placed perpendicularly in a wooden frame B. The bed C is hung on an axle, and is balanced by weights corresponding to the weight of type. The form is secured on it in the same manner as on other presses. The tympan D is attached to the platen instead of the bed. The pressure is given by a combined lever, and the bar or handle E is the same as used in other presses. The ink is enclosed in a box F, in which a roller moves; near this are several rollers, which receive and distribute the ink to a large roller G, that passes over and blacks the type. There is also back of the platen a fly H, which removes the printed sheets. The bed and type are not rolled under the platen as in other presses, but elevated by the hand of the operator, describing a quarter circle, and come against the platen enclosing the paper to be printed between them. The movement of the bed gives motion to the inking establishment, to the tympan, frisket, and fly, all which perform at the proper time their respective offices. The degree of pressure is graduated by a screw, and may be altered in an instant.

The following, extracted from the schedule annexed to the patent, will serve more particularly to illustrate the component parts:

"The platen, or flat surface against which the paper is pressed in printing, is made of wood or metal, and firmly bolted in a strong quadrangular wooden frame, in a perpendicular position. The bed or coffin in which the type is secured may be of wood or metal, hung on an axle and balanced by weights at the extreme end, adapted to the weight of type which may be using. There are two ribs horizontally on the back of the platen, the ends of which project beyond it, and are perforated very near the extreme ends with holes perpendicularly. Between those ribs are placed two levers that interlock in the centre, the outer ends of which have a notch or opening horizontally, and each perforated with two holes. The outer holes in the levers next the ends correspond with the holes in the ribs, in which are placed strong bolts that pass through ribs and levers, and constitute the fulcrum on which the levers move. In each of the openings in the ends of the levers is placed a strong wrought-iron arm, through which the bolt in the inner hole of the lever passes. Each of these arms has a hook or strong projection on the ends that project forward, and a strong screw in the other end that operates on the bolt already described, and has the effect of increasing or diminishing the impression."

"From each arm passes downwards and attached to the wooden frame near their centre, a flat rod of iron connected at the lower end by a joint bending upwards; which joint has a treadle attached to it lying horizontally across and under the press a little raised from the floor." The use of these rods is when the press is at work to close or lock the arms on the bed, which is done by the operator putting his foot on the treadle and pressing it to the floor, which straightens the joints below, and presses open the lower ends of the rods, causing the upper ends to lock the arms on the bed, and being so locked, the operator, by giving the bar or handle a pull, makes the impression on the paper.

"Behind the platen, and a little removed from it, is placed the fly for removing the printed sheets. This fly has its bearing in, and is supported by iron stays attached to the upper rib, on the back of the platen. The fly forms three sides of a square, and is made of wrought-iron. The lower bar lies horizontally, and is the axle on which it turns, the upright part being a little curved near the top, bending over towards the platen and tympan, and has attached to it two flat rods of metal with pivots at each end, on which they turn. These flat rods have attached to them near their ends two fingers each; also near their centres are other small pieces of metal with small weights at their extreme ends. By the action of the small weights the fingers are made to lay hold on the edge of the printed sheet, and by a circular motion of the fly, (which is occasioned by a balancing weight attached to the lower bar,) lays it on a shelf behind the platen."

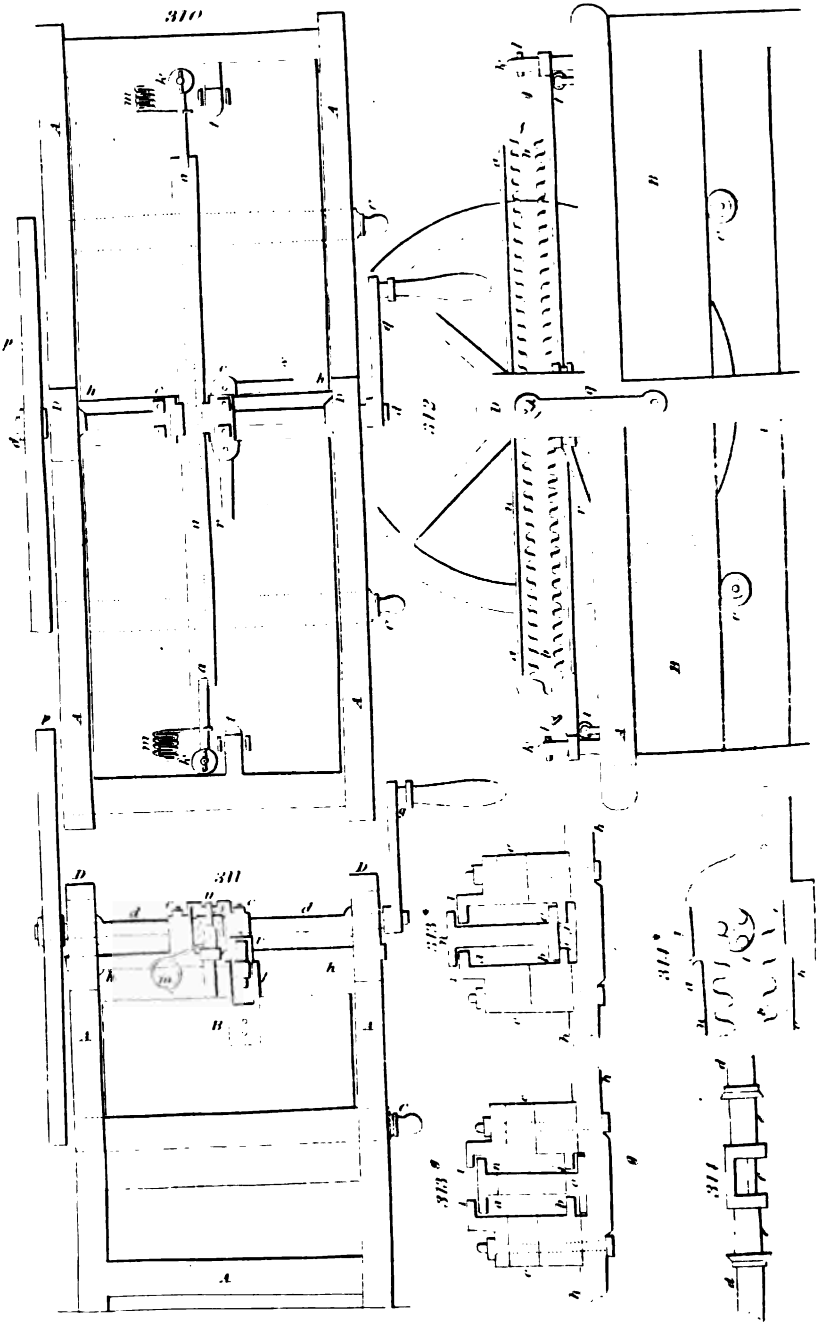
"Across the front end of the wooden frame, and a little distant from the bed or coffin, (when in a horizontal position,) is placed the (ink block or) trough, made of cast-iron, which is filled with ink, and has a cast-iron roller in it nicely fitted to a wrought-iron scraper securely fastened on the top of the trough, which, as this roller turns in the ink, scrapes off all but the quantity required to black the type. This roller has a stop-wheel click and spring, and is turned by a weight wound up in the operation of the press. Near the trough, and between it and the bed, is placed a roller of wood, in length corresponding to the width of the press. It is covered with leather only; and has on the left-hand end a pinion-wheel. The space between this roller and the one in the trough is occupied by two smaller rollers; the larger being of wood, the other of metal. These convey the ink from the roller in the trough to the one covered with leather. Under this roller, and a small distance from it, is a rod of iron extending across the press, with the left end projecting outside the press, which end has a larger pinion-wheel on it, and drives the one before described. On the projecting end of this rod is a roller having a stop-wheel, clicks, and springs. This roller has two leather straps attached to it: on one end of said straps is a weight, on the other a lever, operated upon by the bar or handle, every pull of which winds up the weight, which in its descent assists in distributing the ink," &c. &c.

The specification of the component parts, and their immediate and relative connexion with others, is too long to be inserted here; we shall, however, give an account of the mode of using the vertical press, which will show the simplicity of its operations.

"The operator, having distributed the ink on the elastic roller, and caused it to go over and black the type, then lays a sheet of paper on the tympan, brings down with the right hand the frisket which holds it there; the left hand is then applied to a handle attached to the edge of the bed, and elevates the bed and type to a perpendicular position. The weights attached to the machinery, (which drives the elastic roller over the type,) are by

PECHEYS MANGLE

Plate 41. – *From 310 to 314.* – Page 315



this motion wound up. By the movement of the bed and type, the tympan and paper are brought flat against the platen. The fly is also brought to its position for receiving the printed sheet, and simultaneously with the type striking the paper, the operator places his foot on the treadle, causing the arms to lock on the bed; the right hand is then applied to the bar or handle, and he gives the pull which makes the impression and prints the sheet, the same pull winds up the weight to distribute the ink; the bar or handle then goes back to its position, the foot is removed off the treadle, the arms unlock, and the bed and type return to a horizontal position, and in so doing wind up a weight that assists in distributing the ink. The elastic roller, during the time the impression is making, receives the ink for a second impression, and the instant the bed and type come to a horizontal position, it is by the descent of the weights driven over the type and inks them; at this time also the fly removes the printed sheet."

Six of these presses are now, and have been for some time, constantly employed in one office in Philadelphia, making a saving to the proprietors of many thousand dollars. A comparative statement of the disbursements of the vertical press with one of the horizontal kind, would satisfy the most incredulous. Much might be said of the ingenuity of the invention and the laudable zeal of the inventor, but is presumed unnecessary, as every candid spectator will be convinced of the fact upon examination.]

PECHEY'S MANGLE.

In 1822, the Society of Arts awarded to Mr Elisha Pechey a silver medal and ten guineas for an improvement in the common mangle. The novelty in this mangle is the contrivance for obtaining the alternate forward and backward motion of the box, and consequently of the rollers, by continually turning the winch in the same direction. This way of obtaining the alternate forward and backward motion may frequently be advantageously introduced in other machines; we, therefore, have extracted a description of it from that Society's Transactions.

Fig. 310 is a plan or view of the upper side of the mangle.

Fig. 311 is an end view.

Fig. 312 is a side view; the bottom parts of the frame being represented as broken off, so as to reduce it within the plate; but the whole height is seen in fig. 311.

The same letters of reference apply to the same parts in each figure.

Fig. 313 is a section of a double rack, *a a*, and *b b*, together with the plummer blocks, or guides, *c c*, (which support and guide the rack, or axis, d d, fig 313*,) being cut by a plane in the direction of, and perpendicular to, the axis.

Fig. 313* is a similar section, showing the rack in another situation, as will be hereafter described.

Fig. 314 is a view of part of the shaft, *d d*, showing the two journals, *e e*, which turn and are supported in the plummer blocks, and also the pinion, *f*, of three teeth, forming the middle part of the shaft which works into the racks.

Fig. 314* is a section of the plummer block, cut in the direction of the dotted line, *g g*, fig. 313; and of the pinion, *f*, together with a side view of one end of the racks, *a a* and *b b*.

Figs. 313, 313*, 314, and 314*, are drawn double the size of the former.

A, A, &c. is the frame of the mangle, B B, is a movable box, which contains heavy weights, and C C two rollers, which are all made in a similar way to other mangles.

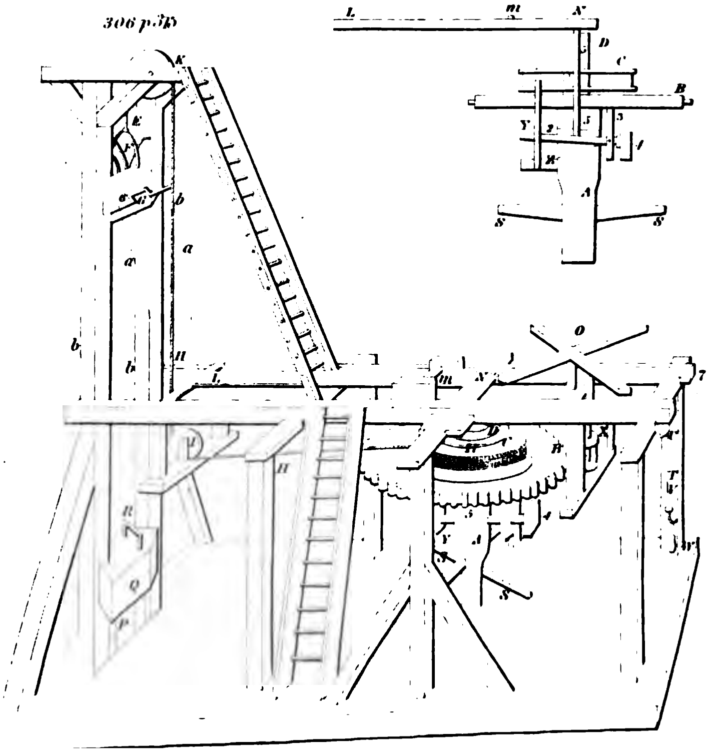
On the upper side of frame A A, &c. are fixed headstocks, D D, which are fixed and kept perpendicular to each other by an iron bar, *h h;* on the upper side of the bar are fixed the plummer blocks *c c;* the upper and lower parts of the plummer blocks have projecting pieces, *i i*, and *j j*, see figs. 313 and 313*, which support and guide the double rack; *a a* and *b b* is the double rack which is fixed parallel to the box B B, by means of two perpendicular studs *k k;* the studs pass loosely through loops in each end of the racks so that the rack is at liberty to move up and down, being at the same time prevented from sliding off by the pins *l l*, fig. 312; each end of the rack is supported by two spiral springs *m m*, fig. 310, fixed on the upper side of the box; the ends of these springs pass through small holes in the ends of the rack, and tend to support it in a middle situation, such a position as that the pinion *f*, fig. 314*, shall be in gear with the upper bar of the rack. The double rack consists of a flat bar of iron, having teeth formed in the internal part of it (as shown in figs. 312 and 314*,) and also two fins or ribs, *n* and *o*, fig. 313, fixed to the upper and lower edges of it, and projecting on each side of the rack. The use of these fins is to support the rack in two situations as shown in figs. 313 and 313*. *d d*, fig. 310, is a shaft or axis, which is supported by the head stocks D D, and by the plummer blocks *c c*, having a fly-wheel, *p*, fixed to one end of it, and a winch, *q*, to the other, by which means the machine is put in motion; in the middle part of the shaft *d d*, is the pinion *f*, shown in fig. 314, which works in the teeth of the rack; in figs. 312 and 314*, the pinion is represented working in the upper rack *a a*.

Now suppose a rotatory motion be given to the winch, the pinion will cause the rack, together with the box, &c. to move in a longitudinal direction till the end of the rack has arrived at the pinion, when it will be seen, by referring to fig. 314*, that the rack cannot pass any further in that direction. By continuing to turn the winch in the same direction as at first, it is evident that the next tooth of the pinion will take into the gap in the end of the rack, and thus cause the rack to slide up the stud *k*, till the fins on each side of the rack are raised above the projecting pieces *i i* and *j j*, fig. 313*, of the plummer blocks: the next succeeding tooth will act in the first gap of the lower rack *b b*, which will cause the rack, together with the box, &c. to move in the contrary direction till the other end of the rack has arrived at the pinion, when a tooth of the pinion will act in the gap in that end, and cause the rack to slide down the stud K, when the next tooth of the pinion will act in the first gap of the upper

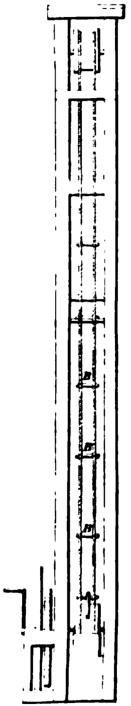
PILE ENGINES.

From 306 to 309.

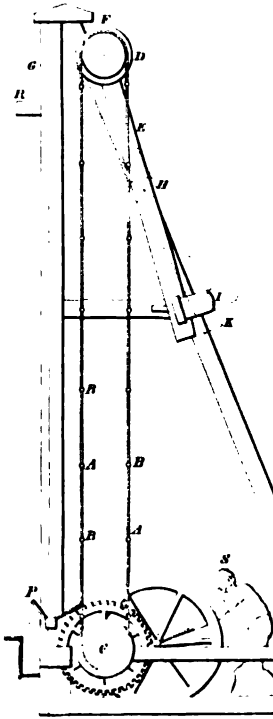
306 p. 315



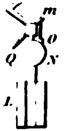
308 p. 316



307 p. 316



309 p. 316



rack, and cause the rack to move in the direction first mentioned, and, by continuing the motion of the winch in the same direction, an alternate motion of the rack-box, &c. is effected.

To replace or change the rollers C C, one of the arms, *r*, or *s*, fig. 310, must be turned on the joint by which it is fastened to the plummer-block, in a direction parallel to the side of the rack as shown in fig. 310.

The arm forms an inclined plane, as shown at *r*, fig. 312, so that when the end of the box, B B, approaches towards the centre of the frame, the friction roller, *t*, (one of which is fixed to each end of the box), passes up the arm or inclined plane *r*, and raises the end of the box, so that the roller, C, may be removed.

◆

PILE-ENGINE.

The pile-engine is a machine by which piles are driven into the ground for the foundation of the piers of bridges, and various other structures.

The method of driving a pile consists in drawing up a very heavy weight, called a ram or hammer, and by disengaging it from the machinery by which it was raised, letting it fall, by the force of gravity, upon the head of the pile. In the most simple machines the weight is drawn up by men pulling a cord over a fixed pulley, and when it has attained a sufficient height allowing the cord to slip from their hands, which permits the weight to descend with considerable force. The two best pile-engines that we have seen are those invented by Mr Vauloué and Mr S. Bunce.

Mr Vauloué's pile-engine may be thus described. A, fig. 306, is a great upright shaft or axle, on which are the great wheel B, and the drum C, turned by horses joined to the bars S S. The wheel B turns the trundle X, on the top of whose axis is the fly O, which serves to regulate the motion, as well as to act against the horses, and to keep them from falling, when the heavy ram Q is discharged to drive the pile P down into the mud in the bottom of the river. The drum C is loose upon the shaft A, but is locked to the wheel, B, by the bolt Y. On this drum the great rope, H H, is wound; one end of the rope being fixed to the drum, and the other to the follower G, to which it is conveyed by the pulleys I and K. In the follower G is contained the tongs F, that take hold of the ram Q, by the staple R, for drawing it up. D is a spiral or fusee fixed to the drum, on which is wound the small rope, T, that goes over the pulley U, under the pulley V, and is fastened to the top of the frame at 7. To the pulley block V is hung the counterpoise W, which hinders the follower G from accelerating as it goes down to take hold of the ram; for, as the follower tends to acquire velocity in its descent, the line T winds downwards upon the fusee upon a larger and larger radius, by which means the counterpoise, W, acts stronger and stronger against it; and so allows it to come down with only a moderate and uniform velocity. The bolt Y locks the drum to the great wheel, being pushed upward by the small lever 2, which goes through a mortise in the shaft A, turns upon a pin in the bar 3, fixed to the great wheel B, and has a weight 4, which always tends to push up the bolt Y, through the wheel into the drum. L is the great lever turning on the axis *m*, and resting on the forcing bar 5, 5, which goes through a hollow in the shaft A, and bears up the little lever 2.

By the horses going round, the great rope H is wound about the drum C, and the ram Q is drawn up by the tongs F, in the follower G, until the tongs come between the inclined planes E, which, by shutting the tongs at the top, opens it at the foot, and discharges the ram, which falls down between the guides *b b*, upon the pile P, and drives it by a few strokes as far into the mud as it will go, after which the top part is sawed off close to the mud by an engine for that purpose. Immediately after the ram is discharged, the piece 6, upon the follower G, takes hold of the ropes *a a*, which raises the end of the lever L, and causes its end, N, to descend and press down the forcing bar 5, upon the little lever 2, which, by pulling down the bolt Y, unlocks the drum C from the great wheel B, and then the follower being at liberty comes down by its own weight to the ram, and the lower ends of the tongs slip over the staple R, and the weight of their heads causes them to fall outward and shut upon it. Then the weight 4 pushes up the bolt Y into the drum, which locks it to the great wheel, and so the ram is drawn up as before.

As the follower comes down, it causes the drum to turn backward, and unwinds the rope from it, whilst the horses, great wheel, trundle, and fly, go on with an uninterrupted motion; and as the drum is turning backward, the counterpoise, W, is drawn up, and its rope T, wound upon the spiral fusee D.

There are several holes in the under side of the drum, and the bolt Y always takes the first of them that it finds, when the drum stops by the falling of the follower upon the ram; until which stoppage the bolt has not time to slip into any of the holes.

The peculiar advantages of this engine are, that the weight called the ram, or hammer, may be raised with the least force; that when it is raised to a proper height, it readily disengages itself and falls with the utmost freedom; that the forceps or tongs are lowered down speedily, and instantly of themselves again lay hold of the ram and lift it up.

The engine was placed upon a barge on the water, and so was easily conveyed to any place desired. The ram was a ton weight; and the guides *b b*, by which it was let fall, were 30 feet high.

Figs. 307 and 308 represents a side and front section of *Bunce's pile-engine.*

The chief parts are A, fig. 307, which are two endless ropes or chains, connected by cross pieces of iron, B, (fig. 308,) corresponding with two cross grooves diametrically opposite in the wheel C, (fig. 307,) into which they are received, and by which means the rope or chain A is carried round. F, H, K, is a side view of a strong wooden frame movable on the axis H. D is a wheel over which the chain passes and turns within at the top of the frame. It moves occasionally from F to G, upon the centre H, and is kept in the positions F, by the weight I, fixed to the end K. In fig. 309, L is the iron ram, which is connected with the cross pieces by the hook *m*. N is a cylindrical piece of wood suspended at the hook at O, which by sliding freely up the bar that connects the hook to the ram, always brings the hook upright upon the chain when at the bottom of the machine, in the position of G P: see fig. 307.

When the man at S turns the usual crane-work, the ram being connected to the chain and passing between the guides, is drawn up in a perpendicular direction, and when it is near the top of the machine, the projecting bar Q, of the hook, strikes against a cross piece of wood at R, fig. 307, and consequently discharges the ram; while the weight I of the movable frame instantly draws the upper wheels into the position shown at F, and keeps the chain free of the ram in its descent. The hook, while descending, is prevented from catching the chain by the wooden piece R; for that piece being specifically lighter than the iron weight below, and moving with a less degree of velocity, cannot come into contact with the iron till it is at the bottom and the ram stops. It then falls, and again connects the hook with the chain, which draws up the ram as before.

In this machine, as well as Vauloué's, the motion of the first wheel is interrupted, so that very little time is lost in the operation; with a slight alteration it might be made to work with horses. It has the advantage over Vauloué's engine in point of simplicity; it may be originally constructed at less expense, and is not so liable to be deranged. Both, however, are ingenious performances, and part of their construction might be advantageously introduced into other machines.

Notwithstanding the ingenuity displayed in the construction of the two pile engines above described, they are now almost entirely superseded by one of much greater simplicity, which is too well known to require description.

To estimate the force of the rammer made use of to drive piles, when it is raised by men drawing it up by a cord, and who, when it is sufficiently elevated, let the cord slip from their hands, its weight ought to be multiplied into the velocity it acquires in falling. Thus if a rammer which weighs 500 lbs. be let fall from four feet, it will fall that height in half a second, and have, at the time of percussion, a velocity capable to carry it uniformly eight feet in half a second. without any further help from gravity; so that we must multiply 500 by 16, or its weight by the number of feet it would fall in a second, and the product, 8000, gives the momentum of the stroke. If a capstan, pulley, or windlass be made to raise the hammer to a considerable height, and then, by an easy contrivance, loosen it at once from its hook, the momentum of the stroke will always be as the square root of the height from which the rammer fell.

Though the momentum, or force of a body in motion, is as the weight multiplied by the velocity, or simply as its velocity when the weight is given, or constant; yet the effect of the blow will be nearly as the square of that velocity;

the effect being the quantity the pile is driven into the ground by the stroke. For the force of the blow, which is transferred to the pile, being destroyed in some certain definite time by the friction of the part which is within the earth, which is nearly a constant quantity, and the spaces in constant forces being as the squares of the velocities; therefore, the effects, which are those spaces sunk, are nearly as the squares of the velocity, or, which is the same thing, nearly as the heights fallen by the ram or hammer to the head of the pile.

FILE-CUTTING MACHINE.

There have been various contrivances for this purpose; but the best we are acquainted with is described in the *Transactions of the American Philosophical Society*, and is as follows:

A A A A, fig. 315, is a bench of seasoned oak, the face of which is planed very smooth. B B B B the feet of the bench, which should be substantial. C C C C the carriage on which the files are laid, which moves along the face of the bench A A A A, parallel to its sides, and carries the files gradually under the edge of the cutter or chisel H H, while the teeth are cut: this carriage is made to move by a contrivance somewhat similar to that which carries the log against the saw of a saw-mill, as will be more particularly described. D D D are three iron rods inserted into the ends of the carriage C C C C, and passing through the holes in the studs E E E, which are screwed firmly against the ends of the bench A A A A, for directing the course of the carriage C C C C, parallel to the sides of the bench. F F two upright pillars, mortised firmly into the bench A A A A, nearly equidistant from each end of it, near the edge, and directly opposite to .each other. G the lever or arm which carries the cutter H H, (fixed by the screw I,) and works on the centres of two screws K K, which are fixed into the two pillars F F, in a direction right across the bench A A A A. By tightening or loosening these screws, the arm which carries the chisel may be made to work more or less steadily. L is the regulating screw, by means of which the files may be made coarser or finer; this screw works in a stud M, which is screwed firmly upon the top of the stud F; the lower end of the screw L bears against the upper part of the arm G, and limits the height to which it can rise. N is a steel spring, one end of which is screwed to the other pillar F, and the other end presses against the pillar O, which is fixed upon the arm G; by its pressure it forces the said arm upwards until it meets with the regulating screw L. P is an arm with a claw at one end marked 6, the other end is fixed by a joint into the end of the stud or pillar O, and by the motion of the arm G, is made to move the ratch-wheel Q. This ratch-wheel is fixed upon an axis, which carries a small trundle-head or pinion R, on the opposite end; this takes into a piece S S, which is indented with teeth, and screwed firmly against one side of the carriage C C C C; by means of this piece motion is communicated to the carriage. F is a clamp for fastening one end of the file Z Z in the place or bed on which it is to be cut. V is another clamp or dog at the opposite end, which works by a joint W, firmly fixed into the carriage C C C C. Y is a bridge, likewise screwed into the carriage, through which the screw X passes, and presses with its lower end against the upper side of the clamp V; under which clamp the other end of the file Z Z is placed, and held firmly in its situation while it is cutting by the pressure of the said clamp V. *7777* is a bed of lead, which is let into a cavity formed in the body of the carriage, something broader and longer than the largest size files; the upper face of this bed of lead is formed variously, so as to fit the different kinds of files which may be required. At the figures 2 2 are two catches, which take into the teeth of the ratch-wheel Q, to prevent a recoil of its motion; 3 3 is a bridge to support one end, 4, of the axis of the ratch-wheel Q; 5 a stud to support the other end of the axis of that wheel.

When the file or files are laid in their place, the machine must be regulated to cut them of the due degree of fineness, by means of the regulating screw L; which, by screwing further through the arm M, will make the files finer, and, *vice versâ*, by unscrewing it a little, will make them coarser; for the arm G will, by that means, have liberty to rise the higher, which will occasion the arm P, with the claws, to move further along the periphery of the ratch-wheel, and consequently communicate a more extensive motion to the carriage C C C C, and make the files coarser.

When the machine is thus adjusted, a blind man may cut a file with more exactness than can be done in the usual method by the keenest sight; for by striking with a hammer on the head of the cutter or chisel H H, all the movements are set at work; and by repeating the stroke with the hammer, the files on one side will at length be cut; then they must be turned, and the operation repeated for cutting on the other side. It is needless to enlarge much on the utility or extent of this machine; for, on an examination, it will appear to persons of but indifferent mechanical skill, that it may be made to work by water as well as by hand, to cut coarse or fine, large or small, files, or any number at a time; but it may be more particularly useful for cutting very fine small files for watchmakers; as they may be executed by this machine with the greatest equality and nicety imaginable. As to the materials and dimensions of the several parts of this machine, they are left to the judgment and skill of the artist who may have occasion to make one; only observing, that the whole should be capable of bearing a good deal of violence.

RAMSDEN'S DIVIDING MACHINE.

This valuable instrument is the invention of Mr Jesse Ramsden, to whom the Commissioners of Longitude gave the sum of 615*l.* upon his entering into an engagement to instruct a certain number of persons, not exceeding ten, in the method of making and using this machine, in the space of two years, say, from the 28th October 1775, to 28th October 1777; also binding himself to divide all sectants and octants by the same engine, at the rate of three shillings for each octant, and six shillings for each brass sectant, with Nonius's divisions to half minutes, for as long time as the Commissioners should think proper to let the engine remain in his possession. Of this sum 300*l.* were given to Mr Ramsden as a reward for the usefulness of his invention; and 315*l.* for his giving up the property of it to the Commissioners.

The following is the description of the engine given by Mr Ramsden, upon oath:

This engine consists of a large wheel of bell-metal, supported on a mahogany stand, having three legs, which are strongly connected together by braces, so as to make it perfectly steady. On each leg of the stand is placed a conical friction-pulley, whereon the dividing wheel rests; to prevent the wheel from sliding off the friction-pullies, the bell metal centre under it turns in a socket on the top of the stand.

The circumference of the wheel is ratched or cut, (by a method which will be described hereafter,) into 2160 teeth, in which an endless screw acts. Six revolutions of the screw will move the wheel a space equal to one degree.

Now a circle of brass being fixed on the screw-arbor, having its circumference divided into sixty parts, each division will, consequently, answer to a motion of the wheel of ten seconds, six of them will be equal to a minute, &c.

Several different arbors of tempered steel are truly ground into the socket in the centre of the wheel. The upper parts of the arbors, that stand upon the plane, are turned of various sizes, to suit the centres of different pieces of work to be divided.

When any instrument is to be divided, the centre of it is very exactly fitted on one of these arbors; and the instrument is fixed down to the plane of the dividing-wheel, by means of screws, which fit into holes made in the radii of the wheel for that purpose.

The instrument being thus fitted on the plane of the wheel, the frame which carries the dividing-point is connected at one end by finger-screws, with the frame which carries the endless-screw; while the other end embraces that part of the steel arbor which stands above the instrument to be divided, by an angular notch in a piece of hardened steel; by this means both ends of the frame are kept perfectly steady and free from any shake.

The frame carrying the dividing-point or tracer, is made to slide on the frame which carries the endless-screw to any distance from the centre of the wheel, as the radius of the instrument to be divided may require, and may be there fastened by tightening two clumps; and the dividing-point or tracer, being connected with the clumps by the double-jointed frame, admits a free and easy motion towards or from the centre for cutting the divisions, without any lateral shake.

From what has been said, it appears that an instrument thus fitted on the dividing-wheel, may be moved to an angle by the screw and divided circle on its arbor; and that this angle may be marked on the limb of the instrument with the greatest exactness by the dividing point or tracer, which can only move in a direct line tending to the centre, and is altogether freed from those inconveniences that attend cutting by means of a straight edge. This method of drawing lines will also prevent any error that might arise from an expansion or contraction of the metal during the time of dividing.

The screw-frame is fixed on the top of a conical pillar, which turns freely round its axis, and also moves freely towards or from the centre of the wheel, so that the screw-frame may be entirely guided by the frame which connects it with the centre: by this means any eccentricity of the wheel and the arbor would not produce any error in the dividing; and by a particular contrivance, (which will be described hereafter,) the screw when pressed against the teeth of the wheel always moves parallel to itself; so that a line joining the centre of the arbor and the tracer continued will always make equal angles with the screw.

Fig. 316 represents a perspective view of the engine.

Fig. 317 is a plan of which fig. 318 represents a section on the line IIA.

The large wheel A is 45 inches in diameter, and has 10 radii, each being supported by edge-bars, as represented in fig. 318. These bars and radii are connected by a circular ring B, 24 inches in diameter and three inches deep; and, for greater strength, the whole is cast in one piece in bell-metal.

As the whole weight of the wheel A rests on its ring B, the edge-bars are deepest where they join it; and from thence their depth diminishes, both towards the centre and circumference, as represented in fig. 318.

The surface of the wheel A was worked very even and flat, and its circumference turned true. The ring C, of fine brass, was fitted very exactly on the circumference of the wheel; and was fastened thereon with screws, which, after being screwed as tight as possible, were well rivetted. The face of a large chuck being turned very true and flat in the lathe, the flattened surface A, fig. 318, of the wheel, was fastened against it with holdfasts; and the two surfaces and circumference of the ring C, a hole through the centre and the plane part round *b*, and the lower edge of the ring B, were turned at the same time.

D is a piece of hard bell-metal, having a hole, which receives the steel arbor *d*, made very straight and true. This bell-metal was turned very true on an arbor; and the face, which rests on a wheel at *b*, was turned very flat, so that the steel arbor *d* might stand perpendicular to the plane of the wheel; this bell-metal was fastened to the wheel by six steel screws.

A brass socket Z is fastened on the centre of the mahogany stand, and receives the lower part of the bell-metal piece D, being made to touch the bell-metal in a narrow part near the mouth, to prevent any obliquity of the wheel from bending the arbor; good fitting is by no means necessary here; since any shake in this socket will produce no bad effect, as will appear hereafter when we describe the cutting-frame.

The wheel was then put on its stand, the lower edge of the ring B, figs. 316, 317, and 318, resting on the circumference of three conical friction pulleys W, to facilitate its motion round its centre. The axis of one of these pulleys is in a line joining the centre of the wheel and the middle of the endless-screw, and the other two placed so as to be at equal distances from each other.

Fig. 316 is a block of wood strongly fastened to one of the legs of the stand; the piece *g* is screwed to the upper side of the block, and has half-holes, in which the transverse axis *h*, fig. 319, turns; the half-holes are kept together by the screws *i*.

The lower extremity of the conical pillar P, figs. 316 and 319, terminates in a cylindrical steel pin *k*, fig. 319, which passes through and turns in the transverse axis *h*, and is confined by a check and screw.

To the upper end of the conical pillar is fastened the frame G, fig. 319, in which the endless-screw turns; the pivots of the screw are formed in the manner of two frustrums of cones joined by a cylinder, as represented at X, fig. 320. These pivots are confined between half-holes, which press only on the conical parts, and do not touch the cylindric parts; the half-holes are kept together by screws *a*, which may be tightened at any time, to prevent the screw from shaking in the frame.

On the screw-arbor is a small wheel of brass K, figs. 316, 317, 319, and 320, having its outside edge divided into 60 parts, and numbered at every sixth division with 1, 2, &c. to 10. The motion of this wheel is shown by the index *y*, figs. 312 and 320, on the screw-frame G.

H, fig. 316, represents a part of the stand, having a parallel slit in the direction towards the centre of the wheel, large enough to receive the upper part of the conical brass pillar P, which carries the screw and its frame; and as the resistance, when the wheel is moved by the endless-screw, is against the side of the slit H which is towards the left hand, that side of the slit is faced with brass, and the pillar is pressed against it by a steel spring on the opposite side; by this means the pillar is strongly supported laterally, and yet the screws may be easily pressed from or against the circumference of the wheel, and the pillar will turn freely on its axis to take any direction given it by the frame L.

At each corner of the piece I, fig. 319, are screws *n*, of tempered steel, having polished conical points; two of them turn in conical holes in the screw-frame near *o*, and the points of the other two screws turn in the holes in the piece Q; the screws *p* are of steel, which being tightened, prevent the conical pointed screws from unturning when the frame is moved.

L, figs. 316, 317, and 321, is a brass frame, which serves to connect the endless-screw, its frame, &c. with the centre of the wheel; each arm of this frame is terminated by a steel screw, that may be passed through any of the holes *g*, in the piece Q, fig. 319, as the thickness of the work to be divided on the wheel may require, and are fastened by the finger-nuts *r*, figs. 316 and 317.

At the end of this frame is a flat piece of tempered steel *b*, fig. 321, wherein is an angular notch; when the endless-screw is pressed against the teeth of the circumference of the wheel, which may be done by turning the finger-screw S, figs. 316 and 317, to press against the spring *t*, this notch embraces and presses against the steel arbor *d*. This end of the frame may be raised or depressed by moving the prismatic slide *a*, fig. 317, which may be fixed at any height by the four steel screws *v*, figs. 316, 317, and 321.

The bottom of this slide has a notch K, figs. 316 and 321, whose plane is parallel to the endless-screw, and by the point of the arbor *d*, fig. 318, resting in this notch, this end of the frame is prevented from tilting. The screw S, figs. 316 and 317, is prevented from unturning, by tightening the finger-nut *w*.

The teeth on the circumference of the wheel were cut by the following method:

Having considered what number of teeth on the circumference would be most convenient, which in this engine is 2160, or 360 multiplied by 6, I made two screws of the same dimension of tempered steel, in the manner hereafter described, the interval between the threads being such as I knew by calculation would come within the limits of what might be turned of the circumference of the wheel: one of these screws, which was intended for ratching or cutting the teeth, was notched across the threads, so that the screw, when pressed against the edge of the wheel and turned round, cut in the manner of a saw. Then having a segment of a circle a little greater than 60 degrees, of about the same radius with the wheel, and the circumference made true, from a very fine centre, I described an arch near the edge, and set off the chord of 60 degrees on this arch. This segment was put in the place of the wheel, the edge of it was ratched, and the number of revolutions and parts of the screw contained between the interval of the 60 degrees were counted. The radius was corrected in the proportion of 360 revolutions, which ought to have been in 60 degrees, to the number actually found; and the radius, so corrected, was taken in a pair of beam-compasses; while the wheel was on the lathe, one foot of the compasses was put in the centre, and with the other a circle was described on the ring; then half the depth of the threads of the screw being taken in dividers, was set from this circle outwards, and another circle was described cutting this point; a hollow was then turned on the edge of the wheel, of the same curvature as that of the screw at the bottom of the threads, the bottom of this hollow was turned to the same radius or distance from the centre of the wheel, as the outward of the two circles before-mentioned.

The wheel was now taken off the lathe, and the bell-metal piece D, fig. 318, was screwed on as before directed, which, after this, ought not to be removed.

From a very exact centre a circle was described on the ring C, figs. 316, 317, and 318, about four-tenths of an inch within where the bottom of the teeth would come. The circle was divided with the greatest exactness I was capable of, first into five parts, and each of these into three. These parts were then bisected four times, (that is to say,) supposing the whole circumference of the wheel to contain 2160 teeth, this being divided into five parts, each would contain 432 teeth; which being divided into three parts, each of them would contain 134; and this space bisected four times would give 72, 36, 18, and 9; therefore each of the last divisions would contain nine teeth. But, as I was apprehensive some error might arise from quinquesection and trisection, in order to examine the accuracy of the divisions, I described another circle on the ring C, (fig. 322,) one-tenth of an inch within the former, and divided it by continual bisections, as 2160, 1080, 540, 270, 135, 67½, and 33¾; and as the fixed wire, (to be described presently,) crossed both the circles, I could examine their agreement at every 135 revolutions; (after ratching, could examine it at every 38¾;) but not finding any sensible difference between the two sets of divisions, I, for ratching, made choice of the former; and, as the coincidence of the fixed wire with an intersection could be more exactly determined than with a dot or division, I therefore made use of intersections in both circles before described.

The arms of the frame L, fig. 322, were connected by a thin piece of brass of three-fourths of an inch broad, having a hole in the middle of four-tenths of an inch in diameter; across this hole a silver wire was fixed exactly in a line to the centre of the wheel; the coincidence of this wire with the intersections was examined by a lens seven-tenths of an inch focus, fixed in a tube which was attached to one of the arms L.* Now a handle or winch being fixed on the end of the screw, the division marked 10, on the circle K, was set to its index, and, by means of a clamp and adjusting-screw for that purpose, the intersection marked 1 on the circle C was set exactly to coincide with the fixed wire; the screw was then carefully pressed against the circumference of the wheel, by turning the finger-screw S, then removing the clamp, I turned the screw by its handle nine revolutions, till the intersection marked 240 came nearly to the wire; then, unturning the finger-screw S, I released the screw from the wheel, and turned the wheel back till the intersection marked 2 exactly coincided with the wire; and, by means of the clamp before-mentioned, the division 10 on the circle being set to its index, the screw was pressed against the edges of the wheel by the finger-screw S; the clamp wire removed, and the screw turned nine revolutions till the intersection marked 1 nearly coincided with the fixed wire; the screw was released from the wheel by unturning the finger-screw S as before; the wheel was turned back till the intersection 3 coincided with the fixed wire; the division 10 on the circle being set to its index, the screw was pressed against the wheel as before, and the screw was turned nine revolutions, till the intersection 2 nearly coincided with the fixed wire, and the screw was released; and I proceeded in this manner till the teeth were marked round the whole circumference of the wheel. This was repeated three times round, to make the impression of the screw deeper. I then ratched the wheel round continually in the same direction without ever disengaging the screw; and, in ratching the wheel about 300 times round, the teeth were finished.

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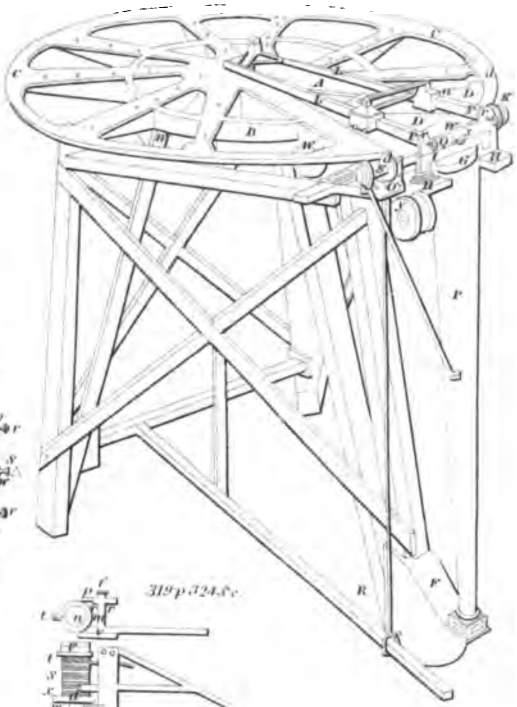
* The intersections are marked for the sake of illustration, though properly invisible, they lying under the brass plate.

RAMSDENS DIVIDING MACHINE &c.

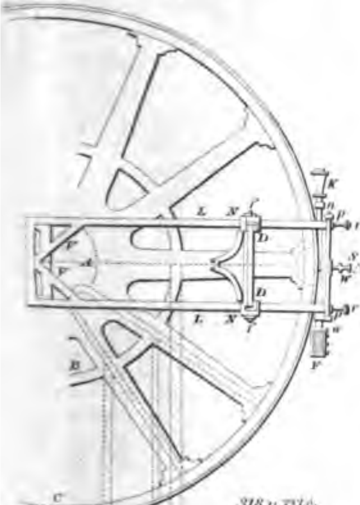
From 315 to 319

Pl. 42.

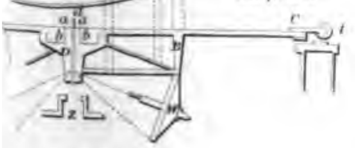
316 p 323 &c.



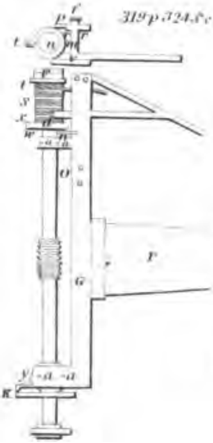
317 p 325 &c.



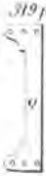
318 p 323 &c.



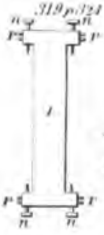
319 p 324 &c.



319 p 321

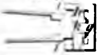


319 p 321

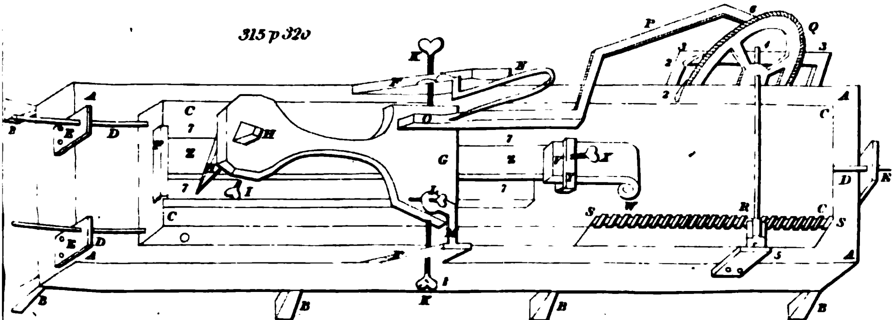


p 321 &c. 319

319 p 321 &c.



315 p 320



It is evident if the circumference of the wheel were even one tooth or ten minutes greater than the screw would require, this error would in the first instance be reduced to $\frac{1}{240}$ part of a revolution, or two seconds and a half; and these errors or inequalities of the teeth be equally distributed round the wheel at the distance of nine teeth from each other. Now, as the screw in ratching had continually hold of several teeth at the same time, and these constantly changing, the above-mentioned inequalities soon corrected themselves, and the teeth were reduced to a perfect equality. The piece of brass which carries the wire was now taken away, and the cutting-screw was also removed, and a plain one, (hereafter described,) put in its place; on one end of the screw is a small brass circle, having its edge divided into sixty equal parts, and numbered at every sixth division, as before mentioned.

On the other end of the screw is a ratchet-wheel *c*, having sixty teeth, covered by the hollowed circle *d*, fig. 320, which carries two clicks that catch upon the opposite sides of the ratchet when the screw is to be moved forwards. The cylinder S turns on a strong steel arbor F, which passes through and is firmly screwed to the piece Y; this piece, for greater firmness, is attached to the screw-frame G, fig. 319, by the braces *v*; a spiral groove or thread is cut on the outside of the cylinder S, which serves both for holding the string, and also giving motion to the lever J on its centre, by means of a steel tooth *n*, that works between the threads of the spiral. To the lever is attached a strong steel pin *m*, on which a brass socket, *r*, turns; this socket passes through a slit in the piece *p*, and may be tightened in any part of the slit by the finger-nut *f*; this piece serves to regulate the number of revolutions of the screw for each tread of the treadle R.

T, fig. 316, is a brass box containing a spiral spring; a strong gut is fastened and turned three or four times round the circumference of this box; the gut then passes several times round the cylinder S, and from thence down to the treadle R, fig. 316. Now, when the treadle is pressed down, the string pulls the cylinder S round its axis, and the clicks catching hold of the teeth on the ratchet carry the screw round with it, till, by the tooth *n* working in the spiral groove, the lever J, fig. 319, is brought near the wheel *a*, and the cylinder stopped by the screw-head, *a*, striking on the top of the lever J; at the same time the spring is wound up by the other end of the girt passing round the box T, fig. 316. Now, when the foot is taken off the treadle, the spring, unbending itself; pulls back the cylinder, the clicks leaving the ratchet and screw at rest till the piece *t* strikes on the end of the piece *p*, fig. 316; the number of revolutions of the screw at each tread is limited by the number of revolutions the cylinder is allowed to turn back before the stop strikes on the piece *p*.

When the endless-screw was moved round its axis with a considerable velocity, it would continue that motion a little after the cylinder, figs. 316 and 319 was stopped; to prevent this the angular lever *κ* was made, that when the lever J comes near to stop the screw *x*, it, by a small chamfer, presses down the piece *κ* of the angular lever; this brings the other end, *ι*, of the same lever forwards, and stops the endless-screw by the steel pin, *μ*, striking upon the top of it: the foot of the lever is raised again by a small spring pressing on the brace *v*.

D, two clamps, connected by the piece *a*, slide one on each arm of the frame L, figs. 316, 317, and 321, and may be fixed at pleasure by the four finger-screws *s*, which press against the steel spring to avoid spoiling the arms; the piece *q* is made to turn without shake between two conical pointed screws *f*, which are prevented from unturning by tightening the finger-nuts N.

The piece *m*, fig. 321, is made to turn on the piece *q*, by the conical pointed screws, *s*, resting in the hollow centres *e*.

As there is frequent occasion to cut divisions on inclined planes, for that purpose the piece, *γ*, in which the tracer is fixed, has a conical axis at each end, which turn in half holes; when the tracer is set to any inclination, it may be fixed there by tightening the steel screws *β*.

Description of the engine by which the endless-screw of the dividing-engine was cut.

Fig. 324 represents this engine of its full dimensions, seen from one side. Fig. 323, the upper side of the same, as seen from above.

A represents a triangular bar of steel, to which the triangular holes in the pieces B and C are accurately fitted, and may be fixed on any part of the bar by the screws D.

E is a piece of steel whereon the screw is intended to be cut; which, after being hardened and tempered, has its pivots turned in the form of two frustrums of cones, as represented in the drawings of the dividing-engine, fig. 320. These pivots were exactly fitted to the half-holes F and T, which were kept together by the screws *z*.

H represents a screw of untempered steel, having a pivot I, which turns in the hole *k*; at the other end of the screw is a hollow centre, which receives the hardened conical point of the steel pin *m*. When this point is sufficiently pressed against the screw, to prevent its shaking, the steel pin may be fixed by tightening the screws Y.

N is a cylindric nut movable on the screw H; which, to prevent any shakes, may be tightened by the screws O. This nut is connected with the saddle-piece P, by means of the intermediate universal joint W, through which the arbor of the screw H passes. A front view of this piece, with a section across the screw-arbor, is represented at X. This joint is connected with the nut by means of two steel slips S, which turn on pins between the cheeks T, on the nut N. The other ends of these slips, S, turn in like manner on pins *a*; one axis of this joint turns in a hole in the cock *b*, which is fixed to the saddle-piece; and the other turns in a hole *d*, made for that purpose in the same piece on which the cock *b* is fixed. By this means, when the screw is turned round, the saddle-piece will slide uniformly along the triangular bar A.

K is a small triangular bar of well-tempered steel, which slides in a groove of the same form on the saddle-piece P. The point of this bar or cutter is formed to the shape of the thread intended to be cut on the endless-screw. When the cutter is set to take proper hold of the intended screw, it may be fixed by tightening the screws *c*, which press the two pieces of brass upon it.

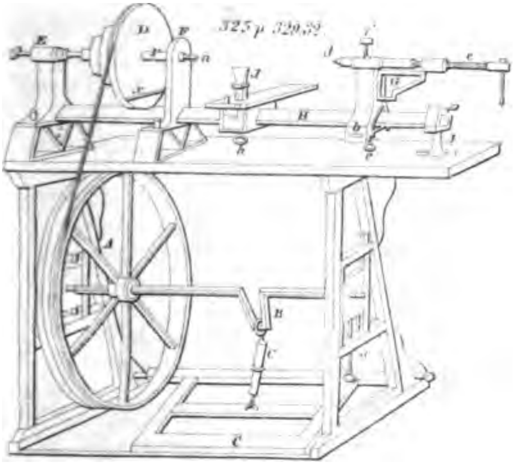
Having measured the circumference of the dividing-wheel, I found it would require a screw about one thread in a hundred coarser than the guide-screw arbor H, and that on the stub E, on which the screw was to be cut, were proportioned to each other to produce that effect, by giving the wheel L 198 teeth, and the wheel Q 200. These wheels communicated with each other by means of the intermediate wheel R, which also served to give the threads on the two screws the same direction.

The saddle-piece P is confined on the bar A by means of the pieces *g*, and may be made to slide with a proper degree of tightness by the screws *n*.

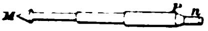
LATHES &c.

From 320 to 330

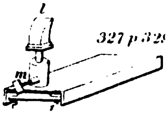
325 p 329.33



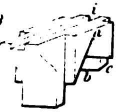
326 p 329



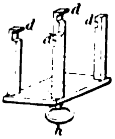
327 p 329



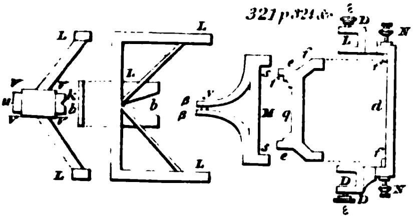
328 p 329



329 p 329



321 p 321 &c.



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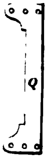

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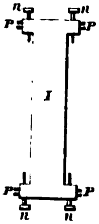
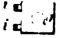


319 h



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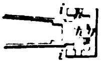
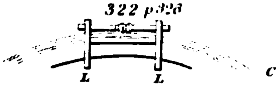
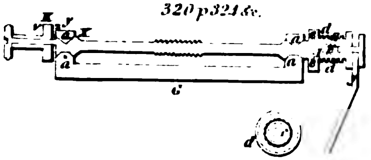


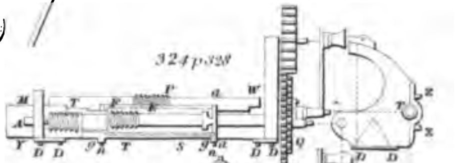
322 p 326



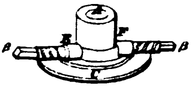
320 p 324 &c.



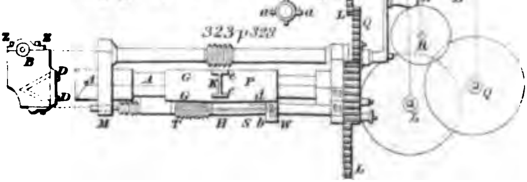
324 p 328



330 p 330



323 p 328



LATHES AND TURNING APPARATUS.

The lathe is a very useful engine for turning wood, ivory, metals, and other materials.

The common lath is composed of two wooden cheeks or sides, parallel to the horizon, having a groove or opening between; perpendicular to these are two other pieces, called *puppets*, made to slide between the cheeks, and to be fixed down at any point at pleasure. These have two points, between which the piece to be turned is sustained; the piece is turned round backwards and forwards by means of a string put round it and fastened above to the end of a pliable pole, and underneath to a treadle or board moved with the foot. There is also a rest which bears up the tool, and keeps it steady.

We shall now proceed to give Mr J. Farey's description of the improvedlat hes manufactured by *Mr Henry Maudslay*, of Margaret-street, Cavendish-square.

A, fig. 325, is the great wheel, with four grooves on the rim; it is worked by a crank B, and treadle C, in the common way; the catgut which goes round this wheel passes also round a smaller wheel D, called the mandrel, which has four grooves on its circumference, of different diameters, for giving it different velocities, corresponding with the four grooves on the great wheel A. In order to make the same band suit, when applied to all the different grooves on the mandrel D, the wheel A can be elevated or depressed by a screw, *a*, and another at the other end of the axle; and the connecting rod, C, can be lengthened or shortened by screwing the hooks at each end of it further out of, or into it. The end M, fig. 326, of the spindle of the mandrel D, is pointed, and works in a hole in the end of a screw, put through the standard E, fig. 325; the other end of the bearing F, fig. 326, is conical, and works in a conical socket in a standard F, fig. 325, so that, by tightening up the screw in E, the conical end, F, may at any time be made to fit its socket; the puppet G has a cylindric hole through its top to receive the polished pointed rod *d*, which is moved by the screw *e*, and fixed by the screw *f;* the whole puppet is fixed on the triangular prismatic bar H, by a clamp, fig. 332, the two ends of which, *a*, *b*, are put through holes, *b*, in the bottom of the puppet under the bar, and the whole is fixed by the screw *c* pressing against it; by this means the puppet can be taken off the bar without first taking off the standard I, as in the common lathes; and the triangular bar is found to be far preferable to the double rectangular one in common use. The rest *j* is a similar contrivance; it is in three pieces; see figs. 327, 328, and 329. Fig. 328 is a piece, the opening, *a*, *b*, *c*, in which is laid upon the bar H, fig. 325; the four legs, *d d d d*, of fig. 329, are then put up under the bar, (into the recesses in fig. 328 which are made to receive them,) so that the notches in *d d d d* may be level with the top of fig. 328: the two beads, *e f*, in fig. 327, are then slid into the notches in the top of *d d d d*, fig. 328, to keep the whole together; the groove *i* is to receive a corresponding piece on *e f*, fig. 327, to steady it; the whole of fig. 327 has a metallic cover, to keep the chips out of the grooves. It is plain that, by tightening the screw *h*, in the bottom of fig. 329, the whole will be fixed and prevented from sliding along the bar H, and fig. 327 from sliding in a direction perpendicular to the bar; the piece *l*, fig. 327, on which the tool is laid, can be raised or lowered at pleasure, and fixed by a screw, *m*. On the end, *s*, of the spindle P, figs. 325 and 326, is screwed occasionally an universal chuck for holding any kind of work which is to be turned. (See fig. 330.) A is the female screw to receive the screw *n*, fig. 325; near the bottom of the screw A is another screw, B B, which is prevented from moving endways by a collar in the middle of it fixed to the screw A; one end of the screw B B is cut right-handed, and the other left-handed; so that by turning the screw one way, the two nuts, E F, will recede from each other, or by turning it the contrary way, they will advance towards each other; the two nuts, E F, pass through an opening in the plate C, and project beyond the same, carrying jaws, like those of a vice, by which the subject to be turned is to be held.

For turning faces of wheels, hollow work, &c. where great accuracy is wanted, Mr Maudslay has contrived a curious apparatus, which he calls a slide-tool, represented by fig. 331, where E E E is the opening to receive the bar H, fig. 325, and it is fixed by the clamp, fig. 332, as before described; the tool for cutting, &c. is fixed into the two holders *b b*, by their screws; these holders are fastened to a sliding plate *a*, which can be moved backwards and forwards by the screw *c*, causing the tool to advance or recede; fig. 333 represents the under side, (turning upwards,) of the part A A, in which the screw *c* is seen fixed at each end, and the nut *d*, which is attached to the under side of the plate *a*, working upon it. When it is necessary, as in the turning of the inside of cones, &c. that the tool should not be parallel to the spindle P, the screw *e*, and another similar one behind, must be loosened, the tool set at the proper angle, and then be screwed tight again. In order to make the piece A A move truly when it is turned round, there is a hole *f*, fig. 333, to receive a knob *g*, fig. 338, upon the plate B, which acts as a centre, and keeps it in its place; there are three holes on each side in the plate B, fig. 336, to put the screw *e* in at different times, thus giving to the tool a greater range than the circular openings S S will admit.

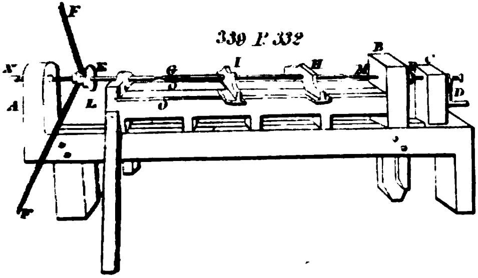
The part E E E E, represented separately, and inverted, in fig. 334, is of cast-iron, and has a screw, *h*, working in it, similar to fig. 333; the nut of this screw is attached to the bottom of the slide H, fig. 335, at *t*, which slides in the groove *i*, figs. 331 and 334; at one end of it is a box containing a screw *m*, to be hereafter described, and at the other is a frame of brass K K. Near the same end of the slide is a pin L, projecting above the plate, which is put through an opening, *j*, in fig. 336, to steady it, while the other end C, of fig. 336, is put through an opening M, in the box D, fig. 335. In the part C is an oblique slit *l l*, to receive a stub which projects from the bottom of the nut *n*, worked by the screw *m*, fig. 335; by this arrangement it is obvious that if the screw *m* is worked, the stub of the nut *n*, acting against the slide of the slit *l l*, as an inclined plane, will move it either backwards or forwards through the opening M; a metal cover *r*, fig. 338, is occasionally put over the opening for the nut *n*, and screw *m*, to prevent the chips from falling in.

Near the four corners of the frame, fig. 336, are four small projections *o o o o*, with inclined sides, which fit into the four openings *p p p p*, of figs. 337 and 331; these openings are cut out in two brass plates, which are screwed on at right angles to the plate B B, figs. 331 and 337; the ends, *q q q q*, of these plates slide between the edges of the frame K K and the box D, so as to prevent any other motion than a vertical one. When this slide tool is used, the puppet G is to be removed or pushed back further from F, and the tool

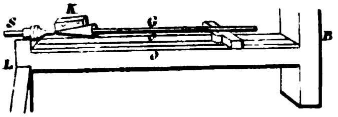
LATHES &c. Pl 11

From 331 to 340

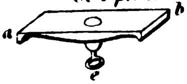
339 P. 332



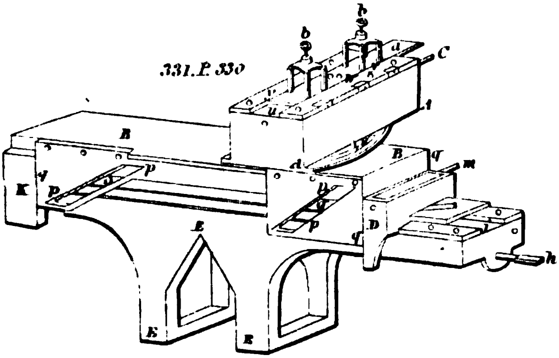
340 p. 332



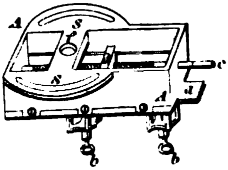
332 p. 329



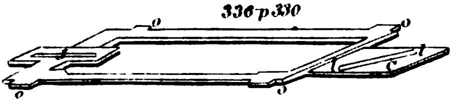
331. P. 330



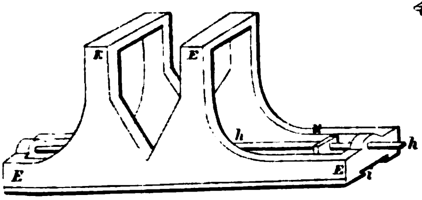
333 p. 330



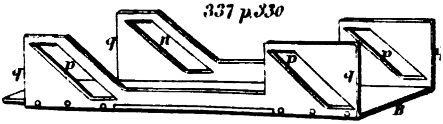
336 p 330



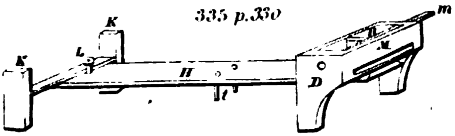
334 p. 330



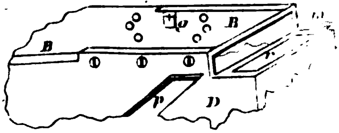
337 p. 330



335 p. 330



338 p. 330



is put upon the bar H, fig. 325, and fixed in the place of the rest *j*, by the clamp, fig. 332, the distance from the centre *n* is adjusted by the screw *h*, which moves the slide, fig. 335, in the grooves *i*, figs. 331 and 334, with the whole apparatus upon it; by the screw *m*, figs. 331 and 335, as before described, the slide, fig. 336, may be moved in a direction perpendicular to the bar H, fig. 325, and its projections *o o*, acting against the slits *p p*, figs. 331 and 337, as inclined planes, will raise or lower the plate B, as is required.

The tool, which has been before fixed in the holders *b b*, can be set at the proper angle by loosening the screw *e*, as previously described; and, lastly, the tool with the holders and slider *a*, can be advanced or withdrawn by working the screw *c*. The nuts of the screws *c* and *h*, fig. 331, are not screwed fast to the sliding plates, but are held by two pins *t*, fig. 335, which fit into grooves *u*, fig. 334, in each side of the nut; by these means the sliding plate can at any time be taken out by only unscrewing one of the brass slides from the grooves *i*, without taking out the screw or nut. In order to make the grooves always fit their slides, the two pieces of brass *y y*, fig. 331, which compose the sides of the groove, have elliptic holes for their screws *v*, so as to admit, when the screws are slackened, of being pushed inwards by the screw *w*, which works in a lump of metal cast with the part A A.

The large lathes which Mr Maudslay uses in his manufactory, instead of being worked by the foot, as represented in fig. 325, are worked by hand; the wheel and fly-wheel which the men turn works by a strap on another wheel fixed to the ceiling directly over it; on the axis of this wheel is a larger one, which turns another small wheel or pulley fixed to the ceiling directly over the mandrel of the lathe; and this last has on its axis a larger one which works the mandrel D, by a band of catgut. These latter wheels are fixed in a frame of cast-iron, movable on a joint; and this frame has always a strong tendency to rise up, in consequence of the action of a heavy weight, the rope from which, after passing over a pulley, is fastened to the frame; this weight not only operates to keep the mandrel-band tight, when applied to any of the grooves therein, but always makes the strap between the two wheels on the ceiling fit. As it is necessary that the workman should be able to stop his lathe, without the men stopping who are turning the great wheel, there are two pulleys or rollers, (on the axis of the wheel over the lathe,) for the strap coming from the other wheel on the ceiling; one of these pulleys, called the dead pulley, is fixed to the axis and turns with it, and the other which slips round it, is called the live pulley; these pulleys are put close to each other, so that by slipping the strap upon the live pulley, it will not turn the axis; but if it is slipped on the other, it will turn with it; this is effected by a horizontal bar, with two upright pins in it, between which the strap passes. This bar is moved in such a direction as will throw the strap into the live pulley, by means of a strong bell-spring; and in a contrary direction it is moved by a cord fastened to it, which passes over a pulley, and hangs down within reach of the workman's hand; to this cord is fastened a weight heavy enough to counteract the bell-spring, and bring the strap upon the dead pulley to turn the lathe; but when the weight is laid upon a little shelf, prepared for the purpose, the spring will act and stop it.

Mr Maudslay has likewise some additional apparatus for cutting the teeth of wheels, in which the face of the mandrel D, fig. 325, has seventeen concentric circles upon it, each divided into a different number of equal parts, by small holes.

There is a thin stop *x*, fig. 325, which moves round on a screw fixed in the standard F; this stop is made of thin steel, and is so fixed, that when it is turned up, and its point inserted into any of the divisions of the mandrel, it will have a sufficient spring to keep it there; the wheel to be cut is fastened, by means of a chuck, to the screw *n*, and after it has been turned, and brought to the proper shape, the rest, *j*, is to be taken away, and the slide-tool substituted; a square bar is then put into the two holders *b b*, fig. 331; this bar has two branches for holding the ends of a spindle, near one end of which is a pulley, and at the other are four chisels fixed perpendicularly into the spindle for cutting out the teeth, (instead of the circular saw commonly used;) the pulley is turned, (with the intervention of several wheels to augment the velocity,) by the same great wheel as the lathe, with 7300 revolutions per minute; the mandrel is then fixed by the stop *x*, fig. 325, and the cutter advanced towards the wheel, by the screw *c*, fig. 331. When it has cut that tooth, the cutter is withdrawn, and the mandrel turned to another division, and a tooth is cut again as before. At that part of the frame of the cutting-spindle where the bar which is fixed in the holders of the slide-tool connects with the two branches, there is a joint, by which the cutting-spindle can be set in an inclining position for cutting oblique teeth, like those which are to work with an endless-screw. The great velocity with which this spindle turns soon generates by friction and resistance a degree of heat sufficient to expand it very sensibly; but this ingenious mechanist, foreseeing such a circumstance, has judiciously compensated for it in his construction, by making the spindle so short as to play loosely in its sockets at the commencement of the motion; but after a few seconds the expansion is such as to cause the whole to fit together as it ought to do, and the work of cutting to proceed with accuracy and safety.

Mr *Smart*, of the Ordnance-wharf, Westminster, has made some very useful improvements in the art of turning, and particularly has struck out a simple method of turning cylinders and cones in wood.

His turning machine is illustrated in figs. 339 and 340, where the legs or stiles L, the puppets A B, the cheeks *o o*, the pikes and screws M, N, R, with the handle D, are but slightly varied from the usual construction. Round the mandrel E passes a band F F, which also encompasses a large wheel, not shown in the figure; and when this large wheel is turned round with moderate swiftness, it communicates a rapid velocity to the mandrel E, and the long piece of wood G, which is proposed to be made cylindrical. This piece is previously hewn into an octagonal form. The cutting frame H contains a sharp iron tool, which is to answer the purpose of the common turning gouge; and which is fitted into the frame so as to project a little beyond its inner part, after the manner of a carpenter's plane-iron for round or ogee work. Then, while the piece G is turning swiftly round by a man working at the great wheel, another man pushes the frame H gently on from L towards M, the lower part of that frame fitting between the cheeks *o o*, and sliding along between them. By this process, the piece G is reduced to a cylinder, moderately smooth; and, in order to render the smoothness as complete as need be, a second cutter, and its frame I, adapted to a rather smaller cylinder than the former, is pushed along in like manner from L to M. This operation may be performed with such speed, that a very accurate cylinder of six feet long, and four inches diameter, may be fixed to the lathe and turned in much less than a minute.

Mr Smart turns a conical end to one of these cylinders with great facility, by means or a cutting-blade fixed in an iron hollow conical frame K, the smaller end of which admits the pike from the screw S, fig. 340, to which one end of the cylinder G is attached; as the cylinder turns rapidly round, the cutter K is conducted gently along it by means of the hollow frame, and soon gives the conical shape to the end of the cylinder, as required.

Some important directions for turning screws, ovals, cubes, rose-work, swath-work, &c. may be seen in *Moxon's Mechanic Exercises:* see also, "Tour pour faire sans Arbre toutes Sortes de Vis," *par M. Grandjeau*, in "*Recueil des Machines et Inventions approuvées par l'Acad. Roy. des Sciences*," tom. v. and Mr Healy's method of cutting screws in the common turning-lathe.

Previously to entering upon the several branches of our manufactures, where machinery will be found in its most complex state, it may, perhaps, be considered not altogether irrelevant, if we take a cursory view of the manner in which we have conducted the reader thus far. In the first place, we have taken up the subject by treating of the Mechanical Powers, and the attributes of matter, as if he were totally unacquainted with the science; and having given him every necessary information with respect to the fundamental principles, have then proceeded to demonstrate the Moving Powers; thus progressively leading him on to a perfect comprehension of the invariable laws of mechanics, before we have ventured to introduce to his notice certain simple machines acting, either separately or conjointly, as accessors to our manufactures. These we have now also portrayed, and so amply, that we feel satisfied he will, though totally destitute of the science at the commencement, be able fully to comprehend and appreciate the several excellencies of the various combinations which will now be unfolded to him.

[*Description* of the *Turning-Lathe* made by Rufus Tyler, and exhibited at the Annual Exhibition of the Franklin Institute of Pennsylvania, 1825, comprising the improvements of Messrs Lukens, Mason, Clarke, Baldwin, and others. Plate *44.

A, the shears of cast-iron, supported by three feet, which serve to connect them firmly at a proper distance from each other, leaving the space between them unobstructed by cross bolts, &c. permitting the slide head and rest to be taken out without detaching the holdfasts; the inner edges are bevelled, as shown in fig. 3, which is an end view of the shears and foot.

B, the standing head, cast in the usual way, the mandrel running in a conical steel collar, as in section, fig. 1. The chuck-screw, fig. 4, and the drill chuck, C, fig. 1, are slightly conical, and are made fast in the mandrel by the key D. The conical end of the back centre is truncated, and works against a hardened die, inserted into the mandrel for that purpose, and sustains the pressure in drilling, &c. and prevents the friction which the acute angle of the cone would otherwise produce.

E, the slide head, having an angular rib screwed underneath and corresponding to the bevel of the shears, is made to compensate for wearing by introducing a thin slip of metal between it and the head.

The slide bar, F, is cylindrical, and is enclosed in a hollow cylinder, which forms the top of the head; the screw has a left hand thread and passes into the slide bar, and is attached by a collar to the cylinder of the head, which secures it from chips and dust. See Section.

G, the rest, grooved underneath to receive the holdfast, as at fig. 5.

The lathe is screwed to a table, which is supported at each end by a case of drawers, leaving a space between for the wheel and treadle.

The wheel is of cast-iron, with curved arms, to prevent breaking by contraction at the time of casting.

From the back part of the treadle is raised an upright, H, from the top of which the pitman, I, extends to the crank.

It is a peculiar property of the crank with a short pitman to turn one of its dead points much quicker than the other; in this arrangement, advantage is taken of that peculiarity, and the slower turn is at the bottom of the tread; the reverse of this takes place in the common mode, and the treadle is too quickly returned upon the foot.]

[*American Slide Rest*, as made by Mason and Tyler, of Philadelphia, including the improvements of other machinists.

A, fig. 1, plate **44, represents a piece of metal grooved underneath, to receive the holdfast, as in the common rest, having a circular projection at B, made flat at the top, forming a bed on which the circular base C rests, and is held fast to it by the screw-bolt D, in the centre of the base.

E, the main-bar connected to the base C by the supports F F, made perfectly flat on its upper surface, having the edges parallel and bevelled under to fit

TURNING LATHE.

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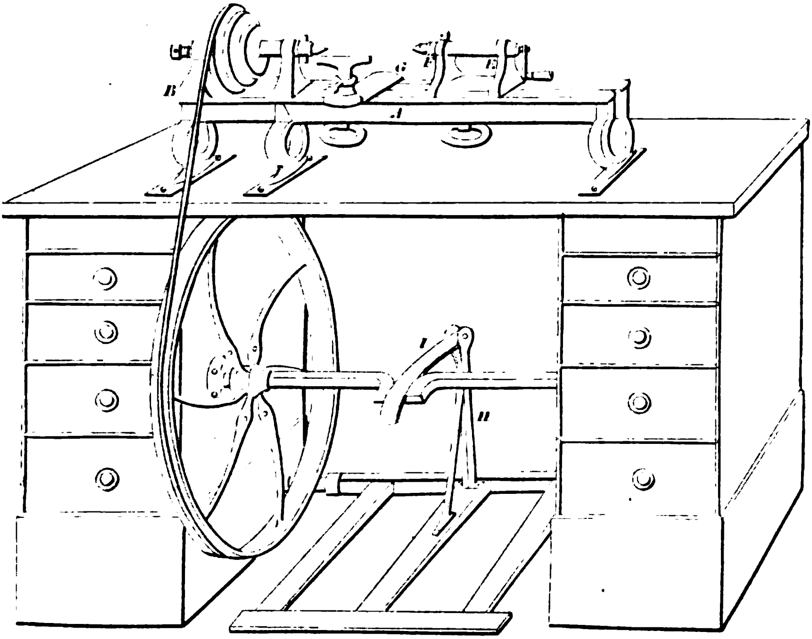
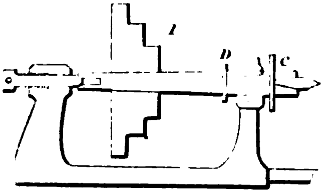
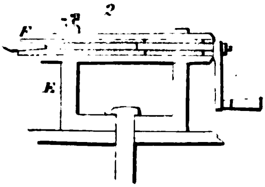
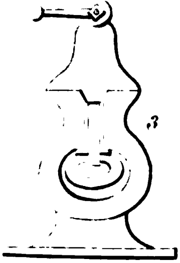
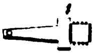










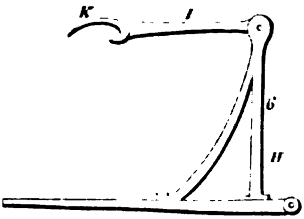


Fig 1. p.384

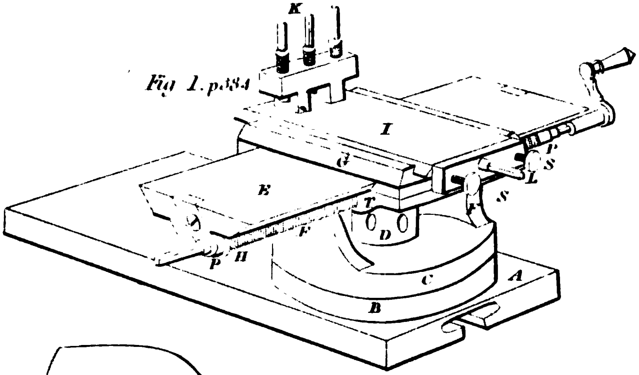


Fig 3.

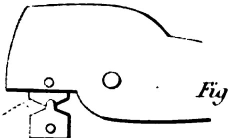
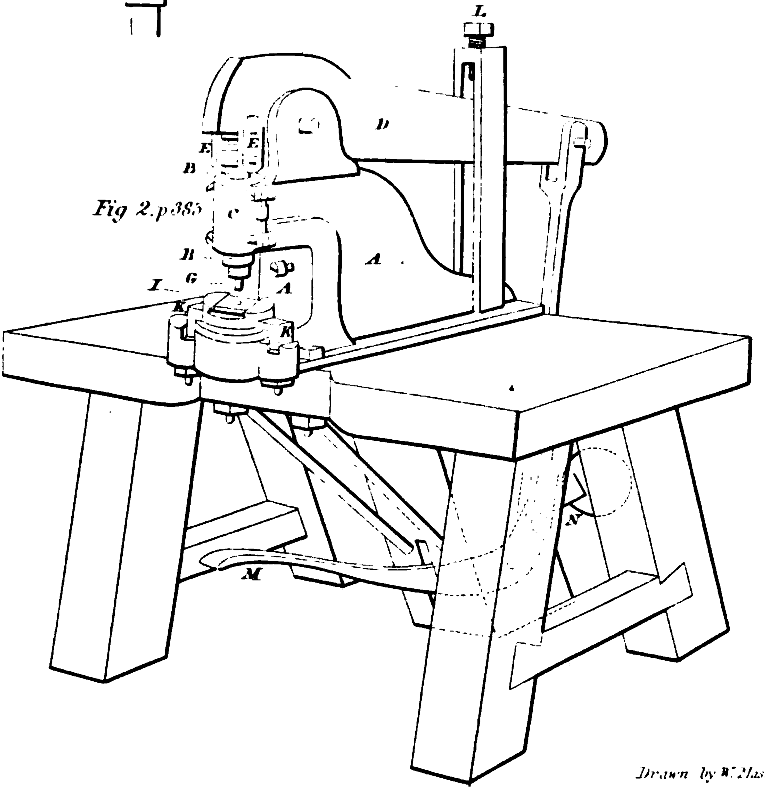
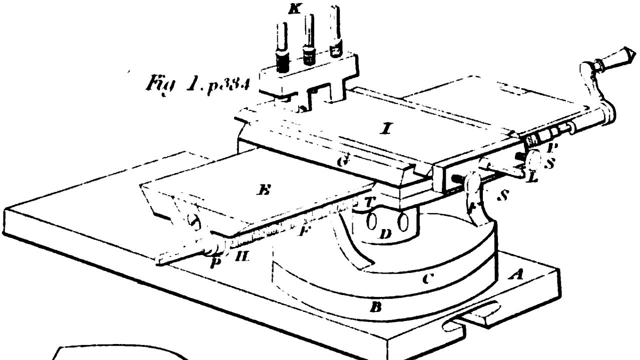


Fig 2. p.385



Drawn by W. Mason.

Fig 1. p384



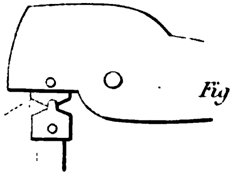
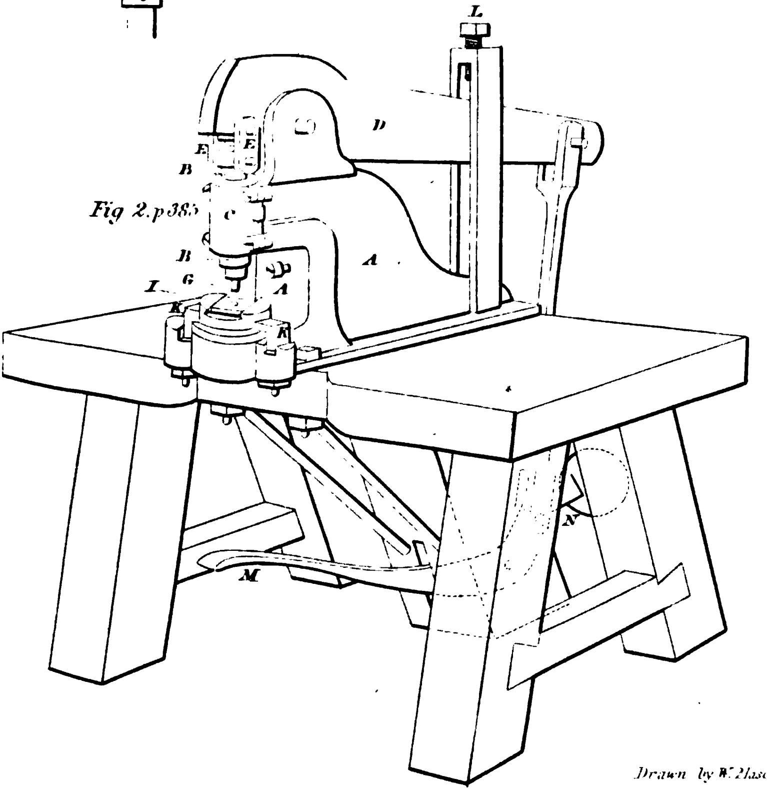


Fig 3.

Fig 2. p385



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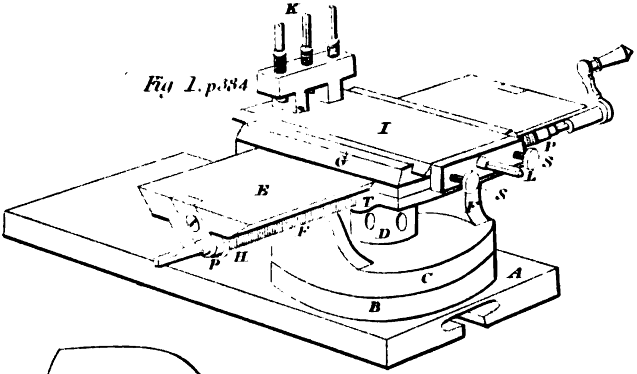

Fig 1. p.384

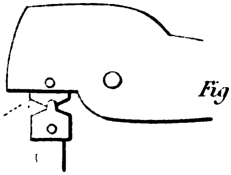

Fig 3.

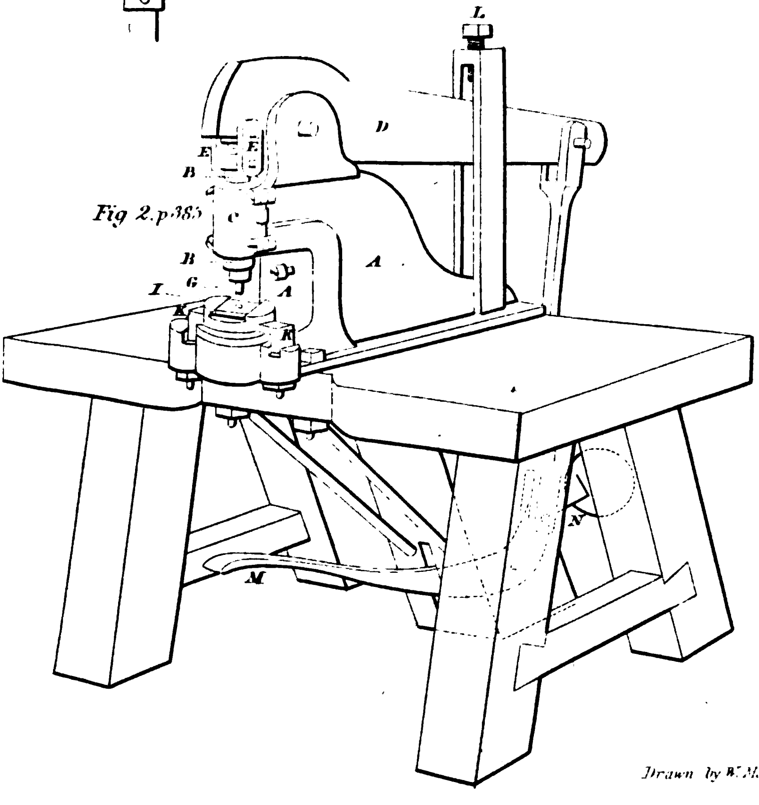

Fig 2. p.385

Drawn by W. Mason.

the dove-tail groove in the lower side of the main slide G; in the top of the main slide is a dove-tail groove, crossing the lower groove at right angles, which receives the cross slide I, on which the cutting tool is plaaed, and may be held by either of the screws, K.

The screw H, which moves the main slide, is supported underneath the edge of the main bar by a collar P, at each end, to protect it from chips, &c. and works in a semicircular nut, T, which is attached to the main slide. The collars P P being smaller than the screw, permit the nut to pass over them and the slide, to be taken off at pleasure; L, a screw by which the cross slide is moved; it passes through the collar M, on the end of the slide I, and works in a nut formed in the bottom of the groove. At each end of the collar piece M is a stop screw S, used in turning grooves of uniform depth, &c.

From the foregoing description, it is obvious that the cutting tool may be moved in the direction of either slide, or in lines at right angles to each other.

For turning cones, cylinders, concave surfaces, facing wheels, &c. the rest may be turned around the centre pin D, by which it is screwed down to the bed.

It is believed that this improved rest combines all the advantages of other instruments of the kind, with greater strength and firmness, and is adapted to the common lathe.]

[*Improved Lever Press*, by Rufus Tyler, for cutting, piercing, &c.

A, fig. 2, plate **44, the body of the press; B, a cylindrical slide working in the box C, and is connected to the lever, D, by the plates E E, a piece of steel, F, is introduced between the top of the slide and the lever, as seen in fig. 3, the use of which is to present sufficient surface to sustain the pressure, and to preserve as nearly as possible the uniform distance of the centres, which connect them.

G is a punch or cutter, the conical shank of which is accurately fitted to a corresponding hole in the bottom of the slide.

The die seat I, is a circular block of metal, expanding into a flanch at the bottom, by which the hooks K K hold it firmly down upon the flat bed upon which it rests.

By this arrangement the most intricate and delicate dies may be set with great facility and the utmost accuracy, by any inexperienced person.

L is a stop screw, to prevent the cutter from entering too deep into the lower die.

The power is applied by the foot at the treadle M, which has a counter balance at N.]

IRON MANUFACTURE.

Works for the manufacture of iron, owing to the great sums necessary to be expended in their erection, have, till within these few years, been confined to a very limited scale; but the spirit of enterprise which has of late, and more especially since the French revolution, manifested itself in nearly the whole of our manufactures, conjoined to the immense capitals acquired by many individuals, and the difficulty of employing them to a better advantage, have given to the manufacture of this highly valuable metal a more decisive character.

The ores from which the metal is extracted are, in this country, found, in general, to consist of iron united with oxygen and various proportions of earthy matter.

The earthy matter in a state of combination with the iron may be divided into two classes; the one called *argillaceous*, from abounding in excess of alumine, or clay; the other *calcareous*, from abounding in lime. The former is by far the most common; indeed it is owing to the ore being so frequently met with in an argillaceous state, that iron-masters are so very inattentive to its quality, and that we sometimes see them use limestone as a flux when the ore already abounds with calcareous ingredients.

Both lime and clay, when separately subjected to the usual heat of the blast-furnace, are infusible; but on being mixed together in certain proportions, are too fusible even for the common purposes of brick-making. An alloy of two metals is also fusible at a temperature much less than the arithmetical mean of the metals themselves.

Such being the case, it is much to be regretted, that iron-masters, in general, are so very ignorant of, and inattentive to, the fusibility of the different combinations of the iron ores, which causes them so frequently to be at a loss what to add to the furnace in order to produce the most fusible cinder. An analysis of the ore, by which they might learn the relative proportions of its earthy constituents, and the quantity of limestone or clay to be added as a flux, would, in the end, prove much to their advantage.

In the usual process of smelting, the coke is always a fixed quantity, and the proportions of ore and limestone are varied according to the quantity of iron to be made, and the working order of the furnace. In proportion to the quantity of lime and ore that is added to the standard quantity of the coke, the furnace is said to carry a greater or less burthen. Some furnaces carry so little burthen as not to produce more than 13 or 14 tons per week; whilst others, with the same sized furnace, will yield 60 and even 70 tons in an equal time. The burthen of the last mentioned furnaces is very great, the ore to the coke being, in some cases, as 13 to 7. The quality of the iron is uniformly inferior.

The burthen of the furnace will vary according as the iron to be made is required to possess more or less carbon; for instance, in making No. 1, or the best iron, which contains the greatest portion of carbon, the burthen must be considerably less than that required to make less carburetted iron, or what is called white-iron, or forge-pig.

To afford a general idea of the proportions of the materials, we shall state the quantities, given by Mr Mushett, as used at a blast-furnace, making good melting iron, which is of an intermediate quality between No. 1 and the forge-pig. The ore is argillaceous, containing on the average about 27 per cent of iron; the coal rather soft, but not very bituminous, and contains a large proportion of carbonaceous matter; and the limestone, which is that abounding in shells, from Critch, in Derbyshire, is very good. It works with a bright tuyere, and receives from the blast about 2,500 cubic feet in a minute, through a circular aperture of 2¾ inches in diameter.

It is usual at this, and most other furnaces, to divide the men into two classes, one class to relieve the other every 12 hours; these periods are called shifts. The average charges of coke per shift are 50, (each 2¼ cwt.) or about six tons. The quantity of calcined ore for the manufacture of good melting iron is upon a par with the coke; and for forge-pig, or the least carburetted variety, six of coke to seven of ore. The limestone unburnt, under the same circumstances, is to coke as 4 to 11; and for melting metal retains a similar ratio. With the above charge per day, that is, for twelve hours, this furnace makes on the average about 40 tons melting iron per week.

After the ore is dug, it is drawn from the pit by the power of steam-engines; it is then, in order to extract the arsenic and sulphur, subjected to a process called *roasting*. This process consists in laying the ironstone in strata with refuse pit-coal, called in Staffordshire *slack*, and setting fire to it on the windward side, burning it in large heaps in the open air.

When the ore has been roasted, it is taken to the smelting or blast furnace, the lower part of which is filled with either charcoal or coke; the coke is always a fixed quantity, and the proportion of limestone added to the ore is according to the quantity of heterogeneous matter with which the metal is combined.

A section of the blast-furnace is represented in fig. 346. A, at the top of the furnace, is an opening for the introduction of the materials; B, the body of the furnace; C, the place where the blast is introduced; and D, a cavity to receive the metal when released from the earthy matter.

The materials in the furnace are, previously to the introduction of the blast, heated simply by the draught of the atmosphere; the coke and limestone to a bright red or white heat, and the iron-ore to a melting heat.

When the blast is introduced, the metal immediately above it is brought into a state of fusion, and penetrates through the fuel into the cavity D. The ore and fuel that were above it sink down to fill up the space left by the ore melted and the fuel consumed. This next comes under the operation of the blast, and is similarly reduced.

The men who attend the furnace keep adding fuel, ore, and limestone, through the opening A, at the top, and the operation of smelting goes on, until the melted iron, in the cavity D, rises nearly to a level with the tuyere-irons, or blast-pipes.

The melted iron is then tapped, by driving a round-pointed bar into a sort of loam, with which the hole is stopped, and run into moulds made in sand; in this state it is called pig or cast-iron.

When the slag, in smelting, has a a greenish-gray appearance, it is a certain sign that the furnace is in excellent order; and when the colour changes to black, it denotes that something is going wrong.

In making the best iron, called No. 1, which possesses the greatest quantity of carbon, it frequently happens that a portion of the iron will unite with a great excess of carbon, and as this carburet is less fusible than the iron, it will, previously to the iron entering into the pig-moulds, be seen floating at the top in the form of scales. The appearance of this substance, called by the workmen *kish*, is a sign that the furnace is working the best sort of iron; indeed it is so common an attendant on the production of the most highly carbonized iron, that the workmen have applied the term *kishy* to that peculiar sort of iron.

The limestone and the earths being much lighter than the metal, float upon its surface, and gradually rising as the metal accumulates, is ultimately discharged over a *dam-stone*, which, though at right angles, we have represented by the dotted lines enclosing the letter I. T is called the *lymp-stone*, and forms a bridge over the cavity in which the liquid cinder rises; *t* is the *lymp-plate*, to give the stone greater firmness, as *e*, which is called the *dam-plate*, does the dam-stone. The cinder, if not taken to mend the roads, is thrown away as useless.

Sometimes two blasts are introduced, as may be seen in fig. 347. That blast, and that furnace, which can reduce the greatest quantity of fuel in a certain time, will always produce the greatest quantity of iron.

The blast conveyed into the furnace is from 1,000 to 4,000 feet per minute; and it is worthy of remark, that the quantity of metal fused does not agree with the ratio of the blast; for instance, a blast of 1,500 feet per minute will manufacture 20 tons of melting iron per week; a blast of 3,000 only 30 tons, and a blast of 6,000, which is double the last, and four times the amount of the first blast, only 36½ tons per week; and again, a blast of 2½ lbs. per square inch will manufacture from 22 to 25 tons per week; while two pipes of the same diameter as the last, with a blast of 3 lbs. per square inch, will never exceed 30 tons.

In the summer months, owing to the increased temperature of the atmosphere, the furnaces yield little better than one half the quantity that they do in winter, and the iron is of an inferior quality. In some manufactories, by adding a greater quantity of fuel, the quality of the iron is preserved; but in others no addition of fuel will compensate for the deficiency either in quality or quantity.

In presenting the section of a blast-furnace, represented in fig. 346, we do not pretend to recommend it as the best form of construction. Different iron-masters have variously constructed their furnaces, and as each of them can boast of being in some degree successful, it were needless to give a description of any particular one; we shall therefore briefly mention, that of whatever materials the buildings be made, care should be taken that they contain no more moisture than is absolutely necessary for their proper construction.

In the erection of the wall, a space of about six inches should be left from the bottom to the top; in this aperture small fragments of sand stone, not exceeding the size of an egg, may be introduced, so that when the expansion, proceeding from the fire-building of the interior, causes the bricks immediately in contact to push outwards, the masses of sand-stone are instantly reduced in size, and filling the interstices occasioned by their former angular shape, occupy much less space, and present to the flame or fire, should it be inclined to penetrate so far, a solid vertical stratum of sand, after having secured the expansion of the furnace to the extent of some inches. The effects of the pressure are thus diverted from the shell of the building, and lost in the pulverization of the sand-stone.

The advantages resulting from this plan may be nearly doubled, by using a double lining of fire-bricks, between each of which and the common building a similar vacancy should be left, but filled with sharp sand, containing no more moisture than serves to compact it in a firm body; as this moisture becomes gradually expelled in the slow heating or annealing of the furnace, the sand occupies less bulk, or, which is the same in effect, is then susceptible of a greater degree of compression when the gradual expansion of the furnace comes on. It is evident that the force is here also diverted against the sand, in place of acting immediately with a tendency to enlarge the circumference of the building.

Over and above these precautions, the annealing or drying of the furnace in a progressive and regular manner ought to be carefully attended to, and continued for two or three months at least.

Many methods have been adopted to obtain a regular and uniform blast. The first that we shall notice, and which is in pretty general use, is, by discharging the air from the blowing-cylinder into an intermediate cylinder of larger diameter, called the regulator; in this vessel is a loose piston, which is forced up by the air from the blowing-cylinder, and being weighed, it descends during the returning stroke, and continues to press the air into the furnace, by which means a more steady and uniform blast is kept up than would be effected by the first cylinder alone.

As this method of regulating the blast has been found to be far from perfect, other means have been resorted to with a view of obtaining the desired end. The one called the water-regulator consists of a large cistern, in which another of less area and capacity is inverted. Through the bottom of the smaller cylinder, which is, from its being inverted, uppermost, a pipe communicates with the blowing-cylinder. This inner cistern is filled with water, as is also the space between the inner and outer cistern to the same level. Now, supposing the air to be forced from the blowing-cylinder through the above-mentioned pipe into the inner cistern, the water, being displaced by the air, will descend in the inner cistern, and rise up between the two vessels till the column of water on the outside be equal to the required force of the blast; this column would be about 4 lbs. upon a square inch, and about nine feet. Another pipe proceeds from the same cavity in the inner vessel to the furnace, and communicates nearly a uniform blast, varying only with the outer column of water, which will be less as the outer surface of the water is greater.

This contrivance, though for some time considered an important discovery, has, in many instances, been abandoned, owing to its carrying water, both in a state of spray, produced by the agitation, and in a state of vapour, into the furnace, by which both the quality and quantity of the iron was materially affected.

Another mode has been attempted to equalize the blast, called the air-vault. The first experiment of this nature was tried at the Clyde iron-works, by excavating a large cavity in a rock, into which the air was forced by the blowing machine; but the trial was unattended by success, partly from the vault not being air-tight, and partly from the moisture which exuded from the rock mixing with the air.

A more successful experiment was made at the Carron iron-works. An air-vault of wrought-iron plate has been employed in one of the furnaces at Bradley, in Staffordshire, which appears to answer very well. Its form is a cylinder about 10 or 12 feet diameter, and 50 or 60 feet long.

According to an average deduced from a series of experiments made by Mr David Mushett,* it appears that when the outer air was from 63° to 68°, the air immediately after its escape from the blowing cylinder into a receiving vessel, was increased from 63° to 90°, and from 68° to 99½°. In an average of thirty experiments the air in the act of condensing was raised 30°. This would have the effect of increasing its volume not less than 1-33 of the whole, and the increased pressure of the blast by this cause alone, would be nearly half a pound upon an inch. Or, in other words, if the air were introduced into the furnace at 60°, the same quantity would be admitted with half a pound less pressure upon an inch than if it were 90°. Hence any means of cooling the air after its condensation, in all seasons of the year, must be attended with beneficial consequences. If the air-vault were made of wrought-iron, and its surface constantly kept wet, the evaporation from so great a surface, if freely exposed on all sides to the air, would cool the air very considerably. Indeed, without the aid of the moisture, the effect would be such as to recommend its adoption. It was supposed, that in the summer season there would be some advantage in bringing the air under ground for a considerable distance before it entered the blowing machine; but the resistance arising from the friction on the sides of the channels through which it must pass has been found to be an obstacle that overrules it.

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* *Edinburgh Encyclopædia*, Dr Brewster, 4to.

The pig-iron which has the smallest portion of carbon is the best adapted for conversion into malleable iron: and as a proof that the pig-iron has only to lose its carbon to become malleable, we shall state the fact, that we have in this country, at this present time, many manufactories upon a large scale, for the express purpose of converting articles made of cast-iron, such as nails, cutlery, &c. into iron perfectly malleable, without altering in the slightest degree the figure given to them in the casting. We have even seen nails made in this way welded together, and when cold bent at right angles in a vice.

The method of releasing the pig-iron of its carbon, or of converting it into what is called *wrought* or *malleable iron*, is, by placing it in an open furnace, termed a *refinery*, and by some a *run-out furnace*, heated by cokes, and subjected to the operation of a very powerful blast. The pig-iron is laid upon the cokes, and is soon melted, leaving much of its impurity behind. This is termed refining it. The metal when melted is run into plates, about four inches thick, and as soon as it becomes set, is thrown into water which makes it more frangible, and easier to be broken.

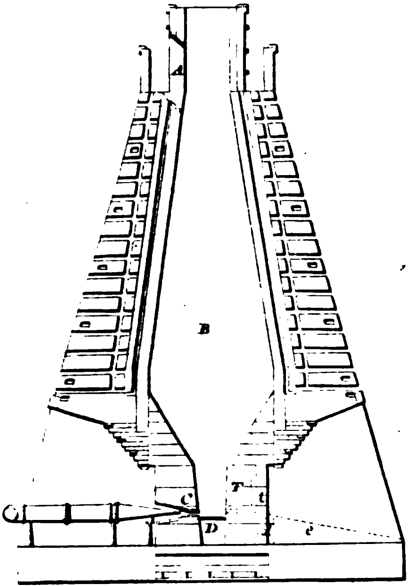
The refining furnace is represented in figs. 348 and 349. A is a recess, or trough, made of cast metal, having a bottom of fire-stone or brick. This recess is surrounded on three sides by a cavity, through which water is constantly passing from the cistern C; *p p* are two pipes connected with the blowing machine, and entering into conical openings in the refining furnace. These pipes are kept cool by water from the pipe *a*, which runs off at the pipe *b c c*. B is a shallow recess, about four inches deep, to receive the melted mass.

When the cake of metal is broken into lumps of a convenient size, it is taken to the *puddling furnace*, where it is heated with coals, without the aid of an artificial blast. As soon as the metal becomes heated, and begins to melt, or has a frosty appearance, the furnaceman throws in a small quantity of water to keep it at a proper temperature, and keeps stirring and moving it about, so that the carbon makes its escape. The water that is thrown in to preserve the temperature also assists in some degree the decarbonization. The quality of iron depends much upon the attention that is paid to it during this process.

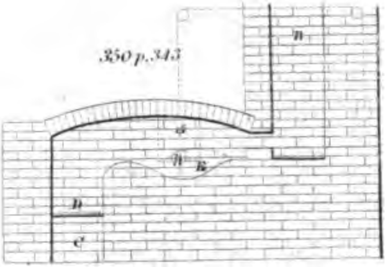
When the iron is deprived of the carbon, or fusible property it before possessed, the furnaceman rolls it up into balls of one-half or three-quarters of a cwt. each. It is then

From 346 to 352

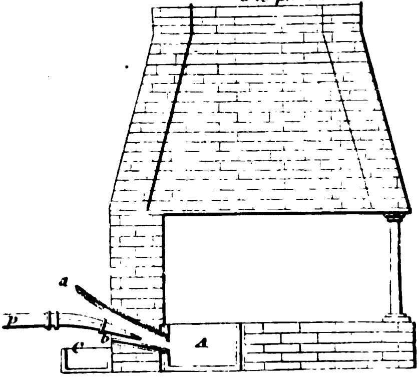
346 p.335



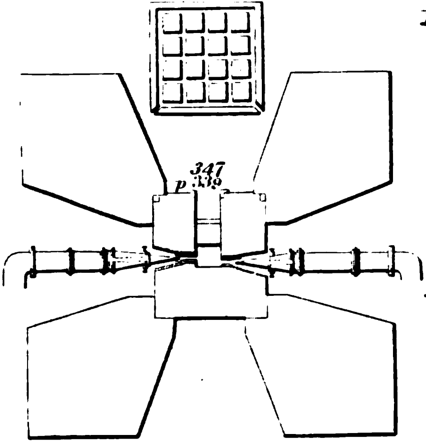
350 p.343



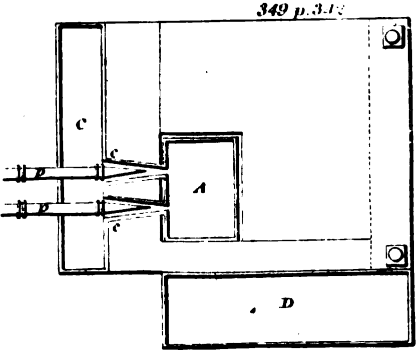
348 p.342



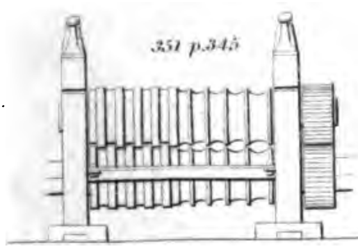
347 p.339



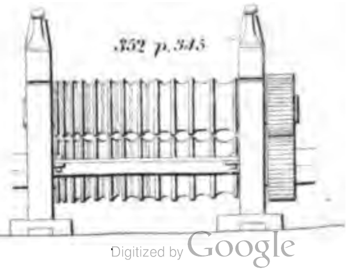
349 p.342



351 p.345

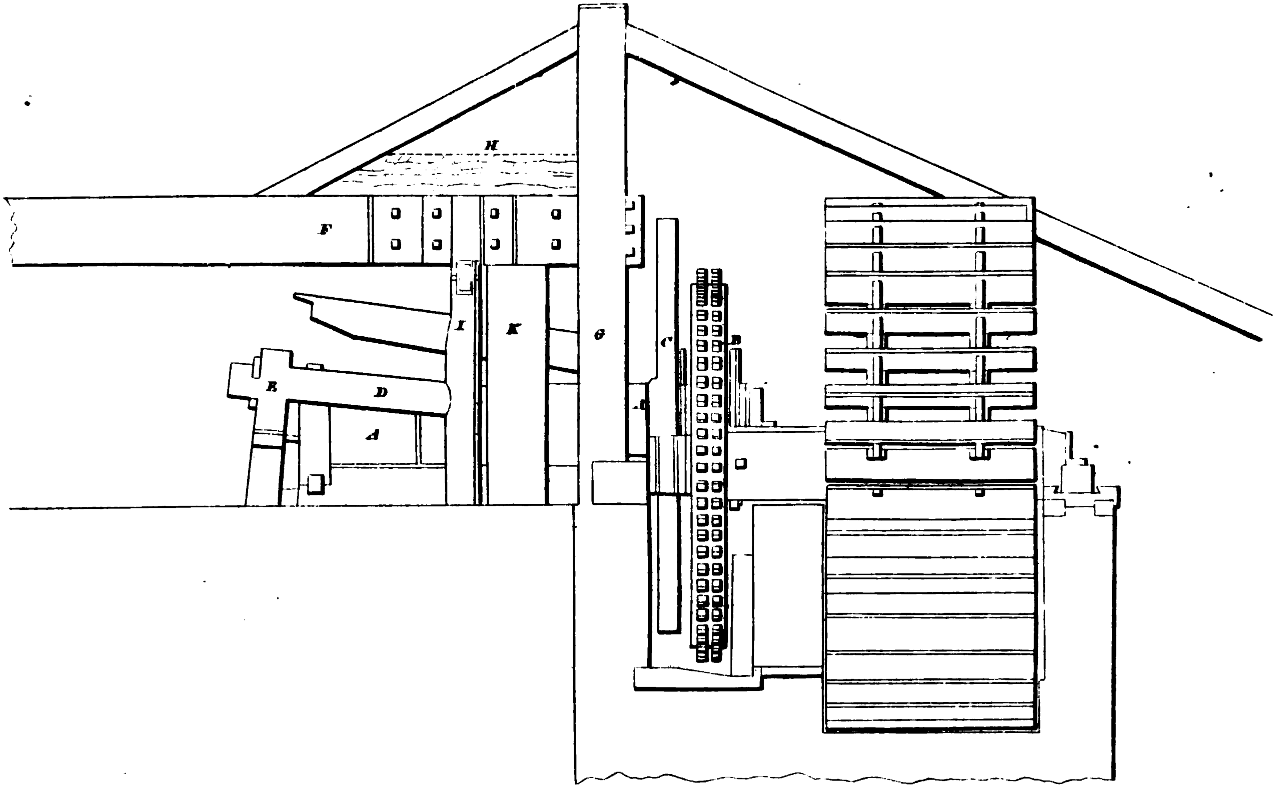


352 p.345



FORGE HAMMER

353 p. 343



brought out of the furnace and placed under a tilt-hammer, or passed through the rolls, or rollers, which consolidates it, and forces out more of the impure parts. A considerable loss in weight is sustained in this process, not only from the iron losing its impurities, but also from the surface of the bloom or bar oxydizing and falling off in scales whilst being worked. The loss which is thus sustained in weight is generally estimated at one-sixth or one-seventh of the whole.

A section and elevation of the puddling furnace is represented in fig. 350, A is the door for the admission of metal, having a small square hole *h*, for the introduction of the rake and other tools used by the furnaceman. B is the chimney; C the ash-pit; and D the grate. At E is a circular cavity, where the prepared metal is laid, and the flame passes over it up the chimney B. The heat of the furnace is so intense that without having the door for a guard, and the small hole *h* for the introduction of the implements, the furnaceman could not approach it; nor indeed can he as it is without suffering great inconvenience. The hole is also of use for him to look into the furnace to observe how the work is going on. At first the light is too intense to be borne, but by practice the eye at length becomes accustomed to it, and is able perfectly to distinguish the different masses as they lay in the furnace.

The iron having undergone this process is taken to the shears and cut into lengths of about one or two feet, and in order to impart closeness and solidity is piled into pieces of seven or eight together, and heated in another furnace, very similar to the one just described. There is no occasion this time to remove them about, for the iron having lost its carbon is infusible. When it is of a sufficient heat, which the furnaceman from practice can easily tell by his eye, it is again brought to either the hammer or the rollers, and is worked into a bar. This is called No. 2 iron. Again, further to improve the quality, it is cut up, piled, and worked over again; and is then called No. 3, or best iron. The more the iron is worked the purer it becomes, and the grain becomes more closely united; but of course it becomes more expensive.

Two kinds of hammer, moved by machinery, are used in iron-works. The one called the *forge-hammer* is represented in fig. 353. The first mover gives motion to the shaft A A, by means of a cog-wheel acting upon the pinion B. The shaft is regulated by a fly-wheel C, and has at the further end a number of cogs, which by passing under the shaft, or helve, D, lift the hammer E. F is a strong horizontal beam, inserted in the post G, and loaded with heavy pieces of metal, at H, to prevent it receiving motion from the hammer. Another large beam of wood, made of either oak, or ash, but most frequently the latter, is inserted in the posts I K. The hammer in its ascent strikes against this beam, called the rabbit, which by its elasticity reacts upon the hammer, and causes it to descend with greater velocity than would be produced by gravity alone.

The construction of a *tilt-hammer* differs from that of the forge, by being poised on a centre of motion, about the middle, or two-thirds of the length of the helve from the head, and from receiving its motion from cogs acting upon the tail of the helve. In some few cases the ash spring is placed over the head of the hammer similarly to that above described; but, in general, the tail of the helve is made to strike against a fixed floor, and the hammer from the force it has received continuing to rise after the tail strikes the floor, the helve bends, and by its elasticity causes the hammer to descend with greater force upon the anvil.

The *tilt-hammer* is represented in fig. 354. It is taken from a tilt-mill made at the Carron iron-works in Scotland, after designs of the celebrated Mr Smeaton. It is adapted for forging iron into bars. The description is extracted from Dr Rees's *Cyclopædia*.

Having described the manner in which the tilt-hammer is connected with the first mover, (drawings of which may be seen in the work,) the author proceeds to explain the figure above referred to; *e* the iron head of the hammer, *f* its centre of motion, and *d* the tail or extreme end, upon which the cogs of the wheel act, and which is plated with iron on the upper side, to prevent it from wearing.

P is the anvil block, which must be placed on a very firm foundation, to resist the incessant shocks to which it is subjected: the centre, *f*, or axis of the hammer, is supported in a cast-iron frame *g*, *h*, called the hirst. When the cogs of the wheel strikes the tail of the hammer suddenly down, and raise the head, the lower side of the tail of the hammer strikes upon a support *n*, which acts to stop the ascent of the head of the hammer *e*, when it arrives at the desired height; but as the hammer is thrown up with a considerable velocity as well as force, the effort of the head to continue its motion, after the tail strikes the stop *n*, acts to bend the helve L of the hammer, and the elasticity of the helve recoils the hammer down upon the anvil with a redoubled force and velocity to that which it would acquire from the action of gravity alone.

To obtain this action of recoil, the hirst *g h* must be held down as firmly as possible; and for this purpose, four strong iron bolts are carried down from the four angles of the bottom plate *h*, and made fast to the solid basis of stone R R, upon which the whole rests; upon this basis are placed four layers of timber, *i k l m*, which are laid one upon another, and the timbers of each layer are laid cross-ways over the others. Each layer consists of several pieces laid side by side, and they are slightly treenailed together, to form a platform. Each platform is rather less than that upon which it rests; so as to form a pillar of solid timber; on the top of which the hirst-frame, *g h*, is placed, and firmly held down by the four bolts, which descend through all the platforms, and have secure fastenings in the solid masonry beneath.

The stop *n* is supported by a similar pillar, but smaller, and composed of three layers: the upper piece *n*, which is seen cross-ways, is about three feet long, and the under side is hollowed, so that the piece bears only upon the two ends, leaving a vacancy beneath it, which occasions it to bend or spring every time the tail *d* of the hammer strikes upon it, and this aids the recoiling action very much.

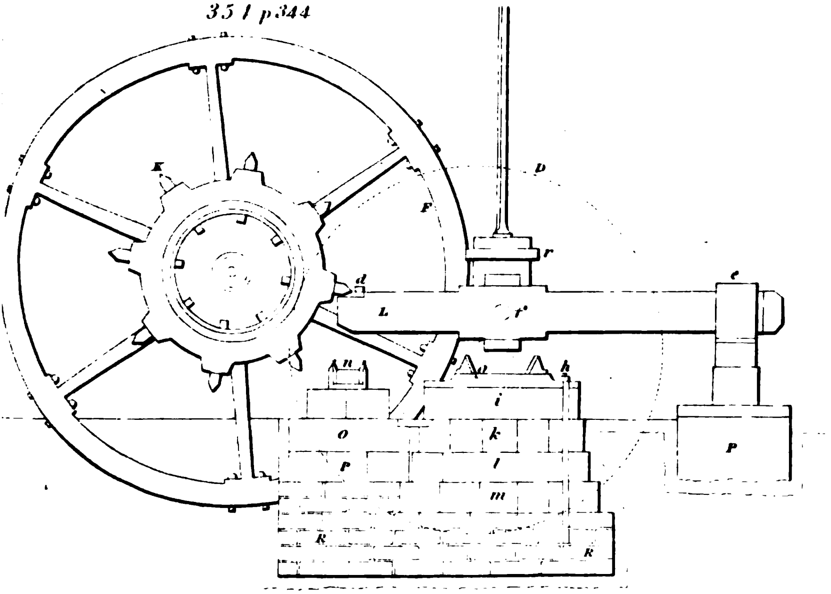
The axis on which the hammer moves is formed by a ring of cast-iron, through which the helve of the hammer is put, and held fast by wedging round it. The ring has a projecting trunnion on each side, ending in an

IRON & STEEL MANUFACTURE

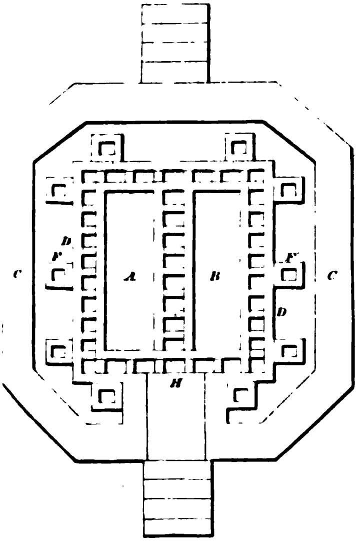
Pl. 48.

From 354 to 356

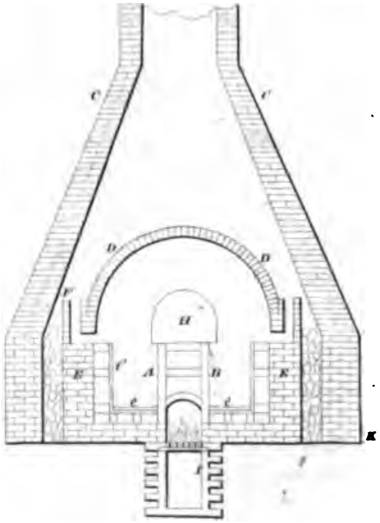
354 p 344



356 p 349



355 p 349



obtuse conical point, which is received in a socket firmly fixed in the hirst-frame *g h*, by screws and wedges, one of which is seen at *r*. These two sockets are thus capable of adjustment, so as to make the hammer face fall flat upon the anvil.

In the Carron iron-works, three hammers are worked from the same shaft. In such case it is necessary to have the three wheels that communicate motion to their respective hammers of different sizes and numbers of cogs to produce that velocity in each hammer which is best adapted for the work it is to perform: thus the wheel for the hammer, which is represented in fig. 352, has eight cogs, and therefore produces eight blows of the hammer for each revolution of the fly-wheel; the wheel for the middle hammer has 12 cogs; and the wheel for the smaller hammer 16; the latter will therefore make two strokes for every one of the great hammers. In fixing the three wheels upon the great shaft, care is taken that they shall produce the blows of the different hammers in regular succession, and equalize as much as possible the force which the water-wheel must exert. The wheels are fixed on the shaft by means of a wedging of hard wood, driven in all round; the wood being capable of yielding a little to the shocks occasioned by the cogs meeting the tails of the hammers, renders the concussion less violent.

The following are the principal dimensions:

The head of the great hammer weighs 3¼ cwt. and it is intended to make 150 blows per minute; it is lifted 17 inches from the anvil at every blow.

The middle hammer is 2 cwt. and makes 225 blows per minute; it is lifted 14 inches each time.

The small hammer weighs 1½ cwt. and makes 300 blows per minute; it is lifted only 12 inches.

To produce these velocities, the great axis upon which the cog-wheels are fixed must make 18¾ turns per minute; and the pinon upon this axis being in proportion with the cog-wheel upon the shaft of the water-wheel as 1 is to 3, the water-wheel must make 6¼ revolutions per minute; the water-wheel being 18 feet diameter, its circumference will be 18 × 3 . 1416 = 56 . 54, or 56½ feet; this multiplied by 6.25 is about 353 feet motion per minute; or divided by 60 = 5.9 feet motion per second for the circumference of the water-wheel.

The tilt-mills employed in the manufacture of steel, do not have the great hammer, but the largest they use is about the size of the middle one, and is adapted for welding faggots of steel to make sheer steel: the other two hammers are about the size of the smallest just described, and are made to work much quicker, viz. from 350 to 400 blows per minute. This is very easily accomplished by making the pinion upon the fly-wheel shaft in proportion to the cog-wheel that acts upon it, and is fixed to the water-wheel, as 1 is to 4.

This highly valuable metal, having undergone these processes, is now sold, and is used by smiths for an innumerable variety of purposes. Indeed, when we reflect upon the many thousands of men, women, and children, who are daily employed in the manufacture and working of this metal; when we consider the immense number of families of miners, melters, refiners, smiths, and other handicraftsmen, who, in all the civilized parts of the world, look up to this particular branch of manufacture for their maintenance and support; when we consider, that the once obscure and inconsiderable village of Merthyr Tydvil, though wild, barren, and sterile, and too poor to produce even the common necessaries of life, has been peopled in the teeth of every obstacle, and, within the space of seventy years, has, through the manufacture of this metal, become by far the largest and most populous town in Wales; we cannot but rejoice that this metal is one of the staple manufactures of Great Britain.

When this metal has become too much worn to answer longer the purpose for which the smith designed it, it is sold to the 'dealers in marine stores,' who assort it into three parcles; one called *coach-tyre*, consisting of the old tyre of coach and other wheels; another *bushel iron*, being remnants of old hoops, and different pieces of iron of similar nature; and another *scrap* or *nut-iron*, consisting of old nails, screws, nuts, and pieces of that description.

These are sold to the manufacturer to be remanufactured. The process of *remanufacturing* is as follows:

Two pieces of iron, each forming three sides of a square, are fixed to a wooden bench, about 10 or 12 inches apart. In the space between these two pieces are placed two rods of iron, about three-eighths of an inch square, one rod being placed close to each of the pieces. On these rods are laid pieces of old hoop, previously straightened, and cut to the proper lengths of 12 or 14 inches, according to the intended length of the faggot. The ends of the hoop rest upon the bottom of each of the pieces of iron first described, and similar pieces of hoop are ranged upon each side, while the interior is filled with bushel or scrap iron. The top is then covered with hoop, and the whole pressed tightly down, and bound, by bringing the ends of the three-eighths rod together, and screwing them round. This is termed a *faggot*, being about 12 or 14 inches long, and six inches square.

The faggot is then carried to a furnace not much unlike the puddling furnace, and when sufficiently heated is brought out, and passed through the rollers, and made into what are called *blooms*. These blooms are generally about two feet long, by three or four inches wide, and two thick.

The blooms are again exposed to the heat in the furnace, and when at a proper temperature are taken out and passed through the rollers, either those represented in fig. 351, or those in fig. 352, accordingly as they are to be made into hoops or bars. The hoop-rollers are represented in fig. 351; the bar-rollers in fig. 352.

Tables of the average weight of bars, squares, and bolts, 10 *feet in length.*

BARS.

Inches.	C.	qr.	lb.	Inches.	C.	qr.	lb.	Inches.	C.	qr.	lb.
6 × ¾	1	1	15	3¾ × ¾	—	3	12	2¼ × ⅝	—	1	23
⅝	1	0	13	⅝	—	2	24	½	—	1	10
½	—	3	19	½	—	2	8	⅜	—	1	1
5½ × ¾	1	1	1	⅜	—	1	20	2⅛ × ¾	—	2	2
⅝	1	0	6	3½ × ¾	—	3	5	⅝	—	1	18
½	—	3	10	⅝	—	2	18	9/16	—	1	14
5 × ¾	1	0	13	½	—	2	4	½	—	1	9
⅝	—	3	23	⅜	—	1	16	⅜	—	1	0
½	—	3	2	3¼ × ¾	—	2	27	2 × ¾	—	1	24
4¾ × ¾	1	0	10	⅝	—	2	14	⅝	—	1	15
⅝	—	3	19	½	—	1	27	9/16	—	1	11
½	—	2	25	⅜	—	1	14	½	—	1	6
⅜	—	2	5	3 × ¾	—	2	22	⅜	—	0	26
4½ × ¾	1	0	4	⅝	—	2	8	1⅞ × ¾	—	1	20
⅝	—	3	13	½	—	1	23	⅝	—	1	12
½	—	2	21	⅜	—	1	10	9/16	—	1	9
⅜	—	2	11	2¾ × ¾	—	2	14	½	—	1	5
4¼ × ¾	—	3	25	⅝	—	2	2	⅜	—	0	24
⅝	—	3	7	½	—	1	20	1¾ × ¾	—	1	17
½	—	2	17	⅜	—	1	7	⅝	—	1	10
⅜	—	2	0	2½ × ¾	—	2	8	9/16	—	1	5
4 × ¾	—	3	19	⅝	—	1	25	½	—	1	2
⅝	—	3	1	½	—	1	15	⅜	—	0	23
½	—	2	12	⅜	—	1	4	1½ × ¾	—	1	11
⅜	—	1	24	2¼ × ¾	—	2	5	⅝	—	1	3
								9/16	—	1	0

SQUARES.				BOLTS.			
Inches.	C.	qr.	lb.	Inches.	C.	qr.	lb.
3	2	3	0	3	2	0	18
2⅞	2	2	3	2⅞	1	3	22
2¾	2	1	8	2¾	1	3	6
2⅝	2	0	11	2⅝	1	2	17
2½	1	3	18	2½	1	1	23
2⅜	1	2	24	2⅜	1	1	11
2¼	1	2	5	2¼	1	0	24
2⅛	1	1	14	2⅛	1	0	9
2	1	0	25	2	—	3	24
1⅞	1	0	8	1⅞	—	3	9
1¾	—	3	21	1¾	—	2	26
1⅝	—	3	2	1⅝	—	2	16
1½	—	2	21	1½	—	2	3
1⅜	—	2	11	1⅜	—	1	24
1¼	—	1	25	1¼	—	1	14
1⅛	—	1	15	1⅛	—	1	5
1	—	1	6	1	—	0	27
⅞	—	0	26	⅞	—	0	20
¾	—	0	19	¾	—	0	15
⅝	—	0	13	⅝	—	0	10
½		0	8	½		0	7

STEEL MANUFACTURE.

When iron has lost all its carbon, and has become malleable, it can be reimpregnated with carbon, to a certain extent, without materially injuring its malleable properties.

The compound of iron and carbon thus produced is called *steel*.

To reimpregnate the iron with carbon, it must be put into a close vessel, called a *cementing pot*, and stratified with powdered charcoal.

The pots are made with a peculiar kind of stone, termed *fire-stone*, which is found abundantly in the neighbourhood of Sheffield. It possesses the properties of not being liable to crack by the heat, or of entering into fusion. These pots in the interior dimensions are from 10 to 15 feet long, and from 24 to 30 inches square. Each bar of iron is completely covered with powdered charcoal, and the last stratum of it is usually made much thicker than the rest, and kept close with a mixture of sand and clay, to prevent the charcoal from entering into combustion with the outer air. Two of these pots only are contained in a furnace at a time, and fire is gradually employed till the heat is little short of what would be required to fuse the steel.

A vertical section, and horizontal plan, of the converting furnace is shown in figs. 355 and 356. In both figures the same letters denote the same parts.

C C is the external cone, built in a substantial manner of stone or brick-work. Its height from the ground to its vertex, in order to procure a good draught of air, should not be less than 40 or 50 feet; and to procure a still stronger heat a cylindric chimney of several feet in length is most generally fixed on the top of the cone. The lower part of the cone, which may be made of any dimensions, is built either square or octangular. The sides are carried up until they meet the cone, giving the furnace the appearance of a cone cut to a square or octangular prism at its base, and exibiting the parabola where every side intersects the cone.

Inside the conical building is a smaller furnace, called the *vault*, built of fire-brick or stone, which will withstand the action of the most intense heat. D D, in the section, is the dome of the vault, and E E are its upright sides, the space between which, and the wall of the external building, is filled with sand and rubbish. A B represent the two pots that contain the iron to be converted into steel. The space between them is about one foot in width, and the fire-grate is directly beneath it. The pots are supported by a number of detached courses of fire-brick, as shown at *e e*, in fig. 355, which leave spaces between them, called flues, to conduct the flame under the pots; in the same manner, the sides of the pots are supported from the vertical walls of the vault, and from each other, by a few detached stones, represented by *f*, placed so that they may intercept as little as possible of the heat from the contents of the pots. The adjacent sides of the pot are supported from one another by small piers of stone-work, which are also peforated to give passage to the flame. The bottoms of the pots are built of a double course of brick-work, about six inches thick; the sides nearest together are built of a single course of stone, about five inches in thickness; and the other parts of the pot are single courses about three inches, the sides not requiring so much strength, because they have less heat and pressure to resist.

The vault has ten flues, or short chimneys, F F, rising from it, two on each side, to carry off the smoke into the great cone, shown in fig. 356, communicating with each side, and two at each end. In the front of the furnace an aperture is made through the external building, and another corresponding in the wall of the vault; these openings form the door, at which a man enters the vault to put in or take out the iron; but when the furnace is lighted, these doors are closed by fire-bricks luted with fire-clay. Each pot has also small openings in its end, through which the ends of two or three of the bars are left projecting in such a manner, that by only removing one loose brick from the external building, the bars can be drawn out without disturbing the process, to examine the progress of the conversion from time to time; these are called the tap-holes; they should be placed in the centre of the pots, that a fair and equable judgment may be formed from their result of the rest of its contents.

a b, in the elevation, is the fire-grate, formed of bars laid over the ash-pit I, which must have a free communication with the open air, that it may convey a current of fresh air to supply the combustion. The ash-pit should also have steps down to it, that the attendant to the furnace may get down to examine by the light, whether the fire upon the whole length of the grate be equally fierce; and if any part appear dull, he uses a long iron hook to thrust up between the bars, and open a passage for the air. The fire-place is open at both ends, and has no doors. The fire-grate is laid nearly on a level with the floor of the warehouse, before the furnace, and the fireman always keeps a heap of coals piled up before the apertures at its ends, so as to close the opening. This forms a very simple and effective door; and when the furnace requires a fresh supply of fuel, a portion of the heap of coals is shoved in by a sort of hoe, and the heap renewed, to stop any air from entering into the furnace, except that which has passed upwards through the ignited fuel, and by that means contributed to the combustion.

The fire-stones composing all those parts of the furnace which are exposed to the action of the heat, are first hewn nearly to a size, and finished by grinding two surfaces together, so that they make very perfect and close joints; when laid together, they are cemented with well-tempered fire-clay, mixed up thin with water. The fire-clay which answers best for this purpose, is that brought from Stourbridge, in Staffordshire, and is the same of which the celebrated Stourbridge crucibles are composed; but very good fire-clay for the purpose is procured from Birkin-lane, near Chesterfield. When the furnace has been once burnt, this clay becomes equally hard with the stone, and is less liable to fly or vitrify in an intense heat than any other known cement.

The flame arising from the ignited fuel upon the grate passes upwards between the pots, and strikes the dome of the vault, from whence it is reverberated down upon the pots, and ultimately escapes through the flues or chimneys of the vault. By this means every part of the pot is exposed to the same degree of heat, which is of great importance.

In order to ascertain when the cementation is perfect, one or two of the bars, having their ends, as before described, projecting from the pots, are taken out of the furnace, and examined.

The blisters upon the surface of the steel, caused by the carbonic oxyd,* is, in general, adopted as a criterion to judge if the metal be sufficiently converted; but this is found frequently to be fallacious, and well it may, for the size of the blisters depend more upon the degree of heat to which the bar has been exposed, than to any other cause.

The time usually required for the conversion of iron into steel is about seven days and nights; and a similar number of days and nights is allowed for the gradual cooling of the furnace.

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* Carbonic oxyd is the union of the two gases which arise from the small portions of carbon and oxyd of iron, of which the iron was possessed, and which is dissipated by the heat of the furnace during this long process.

The steel when taken from the converting furnace is found on its surface to be covered with blisters; and on being broken is found to be full of cavities within; for this reason it is called *blistered steel.*

To make it sound and tenacious, it is put into a furnace, and moderately heated, and is then exposed to the action of the tilt-hammer, which we have already described. This is called *sheer-steel.*

The steel is made of different degrees of hardness, by giving it more or less carbon, according to the different degrees and duration of the heat applied.

The steel used in the manufacture of coach-springs contain the smallest portion of carbon; a somewhat greater quantity is used in the different branches of cutlery, and in the make of agricultural implements; and the greatest dose of all is required for files, which cannot be too hard, provided the steel be sufficiently malleable to be worked.

Cast-steel, which is entirely free from the defects of blistered steel, and is, in some degree, preferable to sheer-steel, is made by placing small portions of the bars of blistered steel into a crucible, capable of containing about 30 pounds weight.

These crucibles are made of Stourbridge clay, mixed with a small portion of powdered charcoal, which makes them much less liable to crack in the heating or cooling. They are furnished with covers, which are more fusible than the body of the vessel, and, on that account, soon enter into a state of partial virtrification; by which means they become closely luted at the time the steel is at a temperature sufficiently high to be destroyed by the oxygen of the atmosphere.

The fuel employed for melting steel should consist of the hardest cokes, which will give a great heat for a longer continuance than the soft cokes.

When the metal is fused it is taken from the furnace, and poured into iron moulds, which form it into ingots of an octagonal shape, about 30 inches long.

These ingots, like the bars of blistered and sheer-steel, are again heated and drawn into bars by the operation of the tilt-mill. By means of this machinery the ingots of cast steel can be drawn into bars one-third of an inch square; and by the hands it can be drawn into rods of a much smaller size.

The manufacture of steel has been greatly improved within a short period, and it can now be fused with so small a portion of carbon, as will admit of its being welded cither with iron or another piece of steel.

The most singular property belonging to steel is that of its hardening by being heated red-hot, and suddenly cooled: and the hotter the steel be made, and the colder the fluid into which it is plunged, the harder will be the steel. Water is generally employed for this purpose; and spring water is considered to be the best. File-makers state, that the salt which is inevitable in their hardening water, makes the steel harder, and they sometimes put sulphuric acid into it for the same purpose.

In hardening steel in thin plates, such as saws, particularly when of cast-steel, quenching in water would cause them to crack, and make them so hard as not to be useful. They have, in consequence, recourse to some substance which is not so good a conductor of heat. Oil, with tallow and bees' wax, and resin dissolved in it, is generally employed for these articles. If the steel be heated red-hot, it mostly returns to its original state. This, however, is sometimes not the case with thin plates of cast-steel. In giving various degrees of heat from the hard state, it becomes more soft and less elastic.

In the year 1789, Mr David Hartley took out a patent for a method of tempering steel by the aid of a pyrometer, or thermometer, applied near to the surface of the article, and at the same time recommended the use of heated oil, in which, (he says,) many dozens of razors or other tools might be tempered at once with the utmost facility, and the various degrees of heat necessary for different purposes might speedily be determined by experiment. (See Nicholson's *Journal*, vol. i. quarto.) An improvement of this principle has been since suggested by Mr Parkes, by providing a bath of oil or of some kind of fusible metal for the tempering of every species of edged tool, which contrivance would, in his opinion, give to this operation a greater degree of certainty than has ever been experienced by those who have conducted such manufactories.

WIRE MANUFACTURE.

Wire is made of various ductile metals; but as the manufacture of the whole is very similar, we shall confine ourselves principally to a description of the manufacture of iron wire, which is by far the most extensive article of commerce.

The process of wire-drawing consists in drawing a piece of metal through a hole in a steel plate, which forms it into a regular and even thread, of great length, according to the quantity of metal supplied.

The first part of the process in the manufacture of iron wire is, to subject the iron to the action of a tilt-hammer till it be reduced to a size that will admit of its being drawn through the plate. The tilt-hammer used is similar to that which we have described in the article "Iron Works." It weighs about 100 pounds, and makes 130 strokes per minute. A smaller tilt-hammer, weighing about 50 pounds, and making 20 strokes per minute, is also used for the wire-work.

To prepare the iron for the draw-plate, the workman heats six or eight inches of the end of a large bar, and works it under the small tilt-hammer until it is drawn out into a small and regular round rod, of about six feet in length. Before it has time to cool another workman straightens it and cuts off with a hammer upon an anvil the rod thus formed, and puts the remainder of the bar into the forge to be again heated.

In manufacturing common wire, the bars may be advantageously run through a pair of rollers, instead of exposing them to the action of the tilt-mill; but as the iron in rolling does not acquire so much tenacity as in the hammering, this process should not be attempted in the manufacture of the best wire.

The rod being thus prepared by one of these methods, is next drawn through a hole in the draw-plate, either by a strong machine with a chain, or else by a lever-machine.

The machines used in the process of wire-drawing are, first,

The common draw-bench, which consists of a strong plank of wood fixed on legs, like a stool or bench. It is represented in fig. 357. A is an axis, fixed in a horizontal position, so that it can be easily turned round by means of the four levers B B; fixed like radii on the end of the axis. C is a strong strap or chain, capable of being wound about the axis or roller, and connected by means of a link with the pincers D. E is a draw-plate, perforated with holes of different sizes, lodged against two strong iron pins *a a*, which are fixed in the bench, and left standing up perpendicularly, so that the plate can rest against them. The wire is passed through the draw-plate E, and is seized by the pincers D, which, by turning the arms or levers B B, winds about the roller, and draws the wire through the plate.

Fig. 358 represents another kind of draw-bench, where a rack and pinion are used, instead of a roller and strap or chain, as above-mentioned. If this machine be turned by a winch the motion is more uniform, which is of importance for some purposes. For instance, if a piece of metal be drawn rapidly through the draw-plate, it will in passing through be greatly compressed, and on emerging will expand a little, but if it be drawn through the plate slowly, it will lose its expansive property. Now in the common draw-bench, or one we first described, the motion communicated by means of the arms B B is very irregular, and the wire is consequently sometimes drawn through the plate with a fast, and sometimes with a slow motion, which causes it to be of different degrees of quality; but in using the rack and pinion, by means of a winch, the motion is regular, and the quality uniform.

In France the roller or windlass is not employed, but the pincers are attached to a lever, which alternately draws them backwards and forwards by the power of the water-wheel.

The pincers are so constructed, that they open and release themselves from the wire when they move towards the draw-plate; but when drawn from the draw-plate close and bite the wire with a force that will draw it through the plate.

A machine of this kind is represented in fig. 359. A B is a wooden lever, which moves round an iron bolt or pin *p*, as a centre of motion; C is an iron link, connected with the upright part of the lever A B, and having its lower end formed like a ring to seize the ends of the pincers. The pincers are supported upon an inclined plate of iron *i*, which has a groove to receive the head of the pincers, to direct them in their motion to and from the draw-plate.

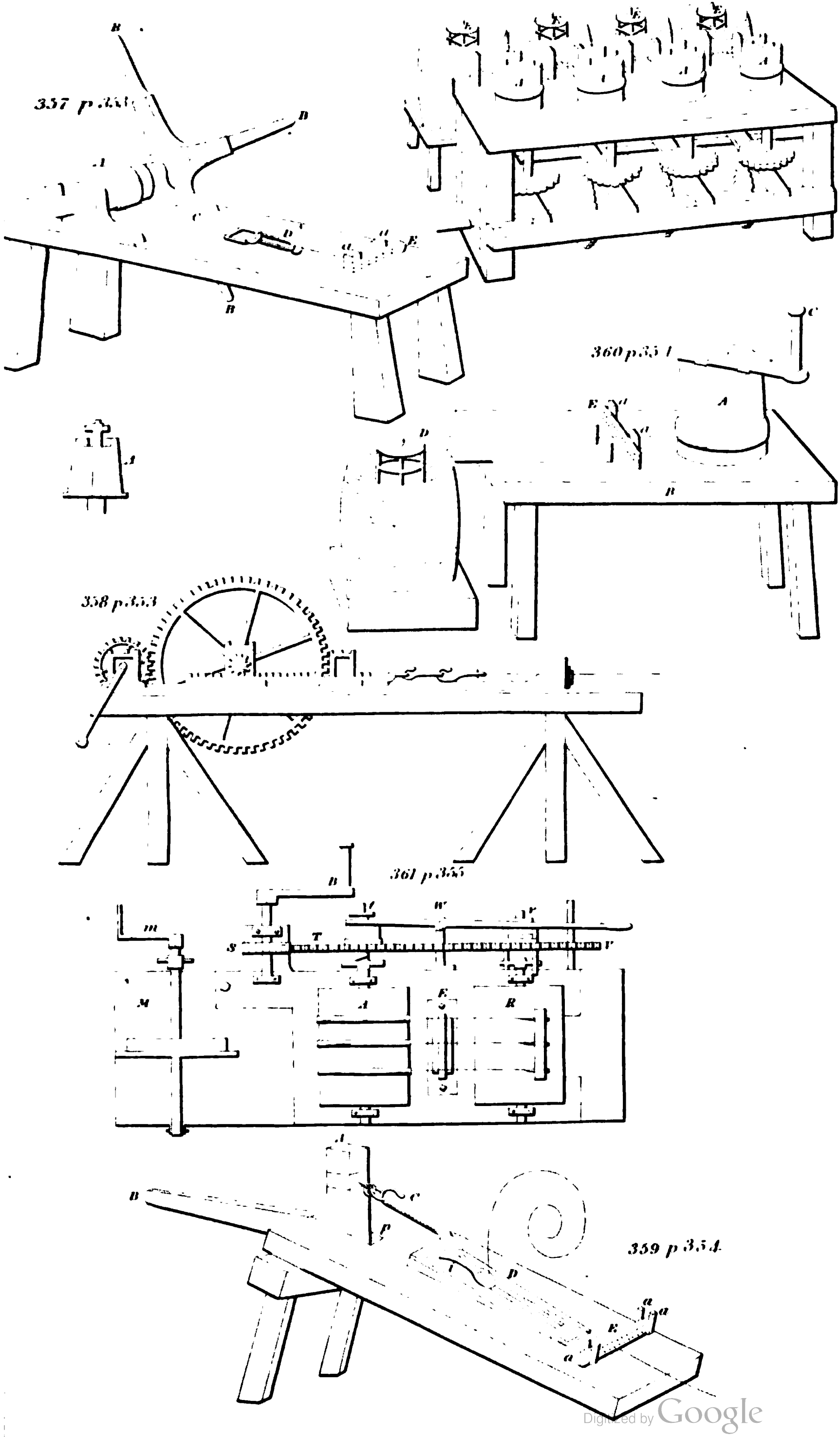
The end B of the lever is depressed by cogs, affixed to the axis of the water-wheel, which draws the wire through the plate; but when the cogs quit the end of the lever, it is returned to its former position, by means of a rope fastened to the end of B, and to a strong wooden pole, fixed to the top of the roof of the building, which acts as a spring. As the lever returns to its place, the pincers, by their own weight, slide down the inclined plane, and in their descent open sufficiently to allow the wire to slide through them, without extricating itself from their jaws; and on the next descent of the lever, they close upon the wire, and draw another portion through the plate.

Three of these machines, of different sizes, are, in general, employed in a wire-mill; the largest draws two inches of the wire at each stroke, and makes about forty-eight strokes per minute; the next four inches; and the third five inches. This last makes about sixty-four strokes per minute. This mode of drawing wire is very simple, but defective; for much time is lost in the returning of the pincers; they sometimes fail to take hold; and wherever they bite they make deep marks upon the wire, which are not more than two inches apart in the great wire, and five inches in the smaller.

Fine wire is always made from the large wire, by reducing it and lengthening it out by repeated drawings. The large wire is usually manufactured at the wire-mills in the country, and sometimes is reduced to small wire at the same establishments, but those who have occasion to use much wire usually purchase the large sort, and reduce it themselves.

A hand machine, represented in fig. 360, is used for this purpose. A is a roller or cylinder, turning upon a vertical pin, fixed in the bench B; C a

WIRE MANUFACTURE *From 357 to 362* *Pl. 12.*



handle turned by manual labour; E the draw-plate; and *a a* the pins against which it rests. The wire to be drawn is placed upon a reel D, which turns upon a vertical pin. This reel is sometimes placed on the table, and sometimes in a tub containing starch-water, or beer that has become acid. This last is to loose the oxyd from the surface of the wire, which it has acquired in the process of annealing. Fig 361 represents a very simple and complete wire-drawing machine, capable of drawing three wires at once. A R are two rollers or barrels with cog-wheels, T V, on the ends of their axis. S is a pinion which is turned round by means of a handle B, and communicates motion to the cog-wheels T V. Both these wheels are fitted upon round parts of the axis of their respective rollers, so as to slip or turn freely round with the same; but a square is formed on the axis outside of the wheel, and a clutch or catch, *t* or *v*, is fitted on this square part, so as to turn always round with the axis. The catch is at liberty to slide upon the axis in the direction of its length, by means of a lever W, which operates upon both catches at once. When either of them is pushed back in contact with the wheel, it intercepts two studs which project from the face of the wheel, and then compels the axis or roller to turn round with the wheel; but when the catch is drawn away from the wheel, then the wheel will slip round upon its axis without communicating any motion. By means of the lever W, only one wheel can be engaged at once, and the other must be free. The draw-plate is firmly fixed between the two rollers, and it has a great many holes; the rollers are long enough to receive three wires at the same time. Each roller has a groove in it parallel to the axis, into which a bar of metal is fitted, and will exactly fill it up.

When the wires are introduced through the holes in the plate, the ends are laid across this groove; the bar is then put in and fastened by a simple contrivance, and it fastens the ends of the wires beneath it, so that they become attached to the roller; then by turning the handle, B, round, the two wheels are put in motion in contrary directions; and that wheel which is connected with its axle by its catch, will turn its barrel round, and wind up the wires so as to draw them through the plate E. The other roller being at the same time detached, its wheel is at liberty to turn round in a contrary direction to the wheel, as fast as the wires are drawn off from it. When the whole length of the wires has been drawn through the plate, they are detached from the roller, the ends introduced through smaller holes in the plate, and fastened again to the roller; then the lever W is shifted, to disengage that wheel which operated before, and engage the other. This being done, the rollers will be turned in an opposite direction, and will wind back the wires, although the handle B is turned the same way round.

After the wire has been drawn three or four times, the metal becomes so hard and fibrous that it would not draw any more without breaking; it therefore requires to be heated in the fire to restore its ductility; for this purpose it must be taken off the barrels. A roller, M, is provided to wind the wire upon and draw it off from the barrel; this roller is turned round by a handle, *m*, fixed on the extremity of its axis; and the wire which is wound upon it in a coil is slipped off sideways. This machine is well adapted to be worked by a mill, because the handle may always be turned in the same way.

Fig. 362 represents a machine that is used for reducing the wire to be employed in the manufacture of musical instruments, or in making cards for wool and cotton. A A A A are conical rollers, called blocks, each having a bush, through which passes a vertical spindle. These spindles are connected with wheel-work, situated beneath the bench, and being round, are capable of revolving without communicating motion to the rollers. When the rollers are required to be engaged, they are lifted up from the bench, till two knobs, fixed in the hollow part of each, come in contact with a cross-bar fixed on the top of each spindle, which immediately carries them round. So long as any wires are supplied by the reels E E E E, the stress of the wires passing through the draw-plates will hold the rollers and spindles clasped together; but as soon as the whole of the wires have passed through the draw-plates, the rollers will become disengaged, and fall upon the bench. The tubs in which the reels are placed contain stale-beer grounds; or starch-water, for the purpose which we have already noticed.

The French draw-plates are the most esteemed, and, in time of war, a good French draw-plate has been sold for its weight in silver. M. Du Hamel, in *Les Arts et Métiers*, vol. xv. gives the following account for the process of making the draw-plates for the large iron-wire.

A band of iron is forged of two inches broad and one inch thick. This is prepared at the great forge. About a foot in length is cut off, and heated to redness in a fire of charcoal. It is then beaten on one side with a hammer, so as to work all the surface into furrows or grooves, in order that it may retain the substance called the potin, which is to be welded upon one side of the iron, to form the hard matter on which the holes are to be pierced. This potin is nothing but fragments of old cast-iron pots; but those pots which have been worn out by the continued action of the fire are not good; the fragments of a new pot which has not been in the fire are better.

The workman breaks these pieces of pots on his anvil, and mixes the pieces with charcoal of white wood. He puts this in the forge, and heats it till it is melted into a sort of paste; and to purify it he repeats the fusion ten or twelve times, and each times he takes it with the tongs to dip it in water. M. Du Hamel says, this is to render the matter more easy to break into pieces.

By these repeated fusions with charcoal, the cast-iron is changed, and its qualities approach those of steel, but far from becoming brittle, it will yield to the blows of the hammer and to the punch, which is used to enlarge the holes. The bar of iron which is to make the draw-plate is covered with a layer of pieces of the potin, or cast-iron thus prepared. It is applied on the side which is furrowed, and should occupy about half an inch in thickness. The whole is then wrapped up in a coarse cloth, which has been dipped in clay and water, mixed up as thick as cream, and is put into the forge. The potin is more fusible than the forged iron, so that it will melt. The plate is withdrawn from the fire occasionally and hammered very gently upon the potin, to weld and in some measure amalgamate it with the iron, which cannot be done at once; but it must be repeatedly heated, and worked until the potion fixes to the iron. The workman then throws dry powdered clay upon it, in order, they say, to soften the potin.

The union being complete, the plate is again heated and forged by two workmen, who draw out the plate of one foot to a length of two feet, and give it the form it is to have. It is well known that cast-iron cannot be worked at the forge without breaking under the hammer; but in the present instance, it is alloyed with the iron-bar, and is drawn out with it. It has also acquired new properties by the repeated fusions with charcoal.

The holes are next pierced whilst the plate is hot. This is done with a well-pointed punch of German steel, applied on that side of the plate which is the iron-bar. It requires four heats in the fire to punch the holes, and every turn a finer punch is employed, so as to make a taper hole. The makers of draw-plates do not pierce the holes quite through, but leave it to the wire-drawers to do it themselves, when the plate is cold, with sharp punches, and then they open the hole to the size they desire; and although this potin is of a very hard substance, the size of the hole may be reduced by gentle blows with a hard hammer, on the flat surface of the plate round the hole.

A great many holes are made in the same plate; and it is important that they should diminish in size by very imperceptible gradations; so that the workman can always choose a hole suitable for the wire he is to draw, without being obliged to reduce it too much at once.

To ascertain the size of the wire, three kinds of guagos are used. The one is made of a piece of wire bent in zigzag, with a space of a different width between every bend; another is made of a steel-plate with notches on the edge; and the other, which is the most accurate, consists of two straight rules of steel put together at an angle. The diameter of the wire in this last is indicated by the depth to which it will enter into the angle; the edges of the rules are divided into equal parts for that purpose, and numbered, to correspond with the different sizes of the wire.

The wire manufactory of Messrs Mouchel, situated at L'Aigle, in the department of L'Orne, is one of the most considerable in France. It furnishes annually in cards for wool-combing only, 100,000 quintals of iron wire, each 100 lbs. A part of this is consumed in France, and the rest is exported to Spain, Italy, Portugal, and even to the shores of the Levant.

They employ the iron manufactured in the departments of L'Orne and La Haute Soane, as being of the best quality. The first produces the best wire for making screws, nails, and pins, as much on account of its hardness as its fine polish, which resembles steel-wire. In this respect it is superior to the iron of Haute Soane; but from its ductility the latter can now be made extremely fine, and it appears to be most free from heterogeneous particles.

The smelted iron, prepared and hammered, being in a state nearly fit for their purpose, is transported at a small expense to L'Aigle, by the rivers and canals. They have a forge to reduce the steel and iron of Normandy, which arrives in large pieces, into small and regular bars.

When the iron is formed into an irregular bar of about a centimeter, near four-tenths of an inch in diameter, they begin to draw it into wire. Although it be already much extended by hammering, it is in the first place passed four times through the drawing-plate; then its molecules become disposed lengthways, and exhibit fibres at their utmost extension. The fibres must be removed by means of heat, which disperses and divides them; and after that the wire may again be reduced three numbers. The fibres which are reproduced by this operation are again removed by heat. The whole process is five times repeated, consequently the wire is passed through fifteen numbers; after which, a single exposure to the fire is sufficient to fit it for passing six others, whereby it is reduced to the thickness of a knitting-needle.

The steel-wire, being much harder, requires to be passed through forty-four numbers, and to be annealed every other time.

The machine which draws the steel-wire must go slower than that which draws the iron; for the first being very hard, and offering more resistance to the drawing-plate, should be pulled out with more care, since the quickness ought to be proportioned to the resistance, and reciprocally; and if they depart from this principle the results will vary. Thus, for example, the iron of the department of L'Orne, which is more compact than that produced at Haute Soane, if drawn by the same machines, augments to hardness, and is weakened when it is brought to too great a degree of fineness. But this iron, which is very hard, and capable of receiving a very high polish, is to be preferred for certain uses.

In order to anneal the wire, they formerly employed a large and elevated furnace, with bars of cast-iron to support the wire in the middle of the flames. It contains 7000 pounds weight, so contrived as to contain equal portions of each number. They are so arranged that the thickest wires receive the strongest heat; therefore, the whole is equally heated in the same space of time.

The operation lasts three hours with a fire well kept up, and it might be imagined that this apparatus was completely adapted to the purpose; but there are imperfections in this method, because it leaves the wire exposed to the contact of the atmospheric air, the oxygen of which it seizes with extreme avidity; whence a considerable quantity of oxyd is occasioned, and also an operation to free it from the scales, which consists of beating the bundles of wire with a wooden hammer wetted with water.

Notwithstanding this precaution, there often remains a portion of oxyd adhering to the surface of the metal, which streaks the draw-plate, or fixes on the wire, and gives it a tarnished appearance, and causes it to break when it is brought to a great degree of fineness. This furnace is only used for the steel-wire or the iron from L'Orne, which is less liable to change; and besides, being harder, is not easily attacked by the oxygen.

In order to diminish the waste that the fire occasions, they have contrived another process, which consists in dipping the bundles of wire into a basin of wet clay before they put them into the furnace; and they are left in the furnace to dry before the fire is lighted, without which precaution the clay would peel off from the iron.

For making wire for cards, M. Mouchel invented another furnace. It is round, and about one metre six decimetres in diameter, and one metre eight decimetres in height, without including its parabolic arch, and the chimney above it. The interior is divided by horizontal grates into three stories; the lowest receives the cinders, the second is the fire-place, and into the third, or upper place, they slide a roleau of wire, weighing 150 kilogrammes, which is enclosed in a space comprised between two cast-iron cylinders, being luted to prevent the admission of air between them. The flames circulate about the outside of the first, and within the interior of the second, which defends the wire from atmospheric air. The diameter of the largest cylinder is about one metre four decimetres; that of the second one metre; thus the space comprised between them is two decimetres, on an elevation of five decimetres. There must be several pair of cylinders provided, because whilst one pair is in the furnace, another must be prepared to receive a fresh roleau of wire; they are changed every hour by means of a long iron leaver, with which a single man can easily push them in, and draw them out again, as the cylinder slides on cast-iron rails.

They are very careful not to open the cylinders immediately on their being drawn out of the fire; for the roleaus of wire contained in them, being still red, would oxydate quite as much as if they had been heated in the midst of the flames without the least precaution.

The opening contrived for the passage is on the side, and has a door of cast iron, with a groove which winds round the furnace; the fire-place has one something similar to it; that of the ash-hole is vertical, in order that it may be raised to increase the fire at will.

When the iron-wire is reduced to the thickness of a knitting-needle, it is made up into bundles of 125 kilogrammes, (275 lbs.) each, into a large iron vessel, in order to anneal it sufficiently to be reduced for the last time. This vessel is placed upside-down in the middle of a round furnace, which is so constructed as to sustain burning coals all round it, and of which it consumes 35 kilogrammes, (77 lbs.) before the operation is completed. The cover must be carefully luted, as the slightest admission of air is sufficient to burn the external surfaces of the wire to an oxyd, which cannot afterwards be reduced.

When one of these vessels is sufficiently heated, it is filled with water containing three kilogrammes, (six pounds and a half,) of tartar, and suspended over the flames of the furnace to make it boil; this solution, without attacking the metal, frees it from the grease and the little oxyd that adheres to it. This is the last operation in which the wire is exposed to the fire, and it is then in the proper state for being reduced to the utmost degree of fineness it is capable of sustaining, and will preserve enough of the effect of the annealing to require it no more; but when the natural hardness of the iron varies, this last exposure to the fire should take place in proportion to its thickness. As steel loses its capacity of extension much sooner than iron, it is annealed until it is no thicker than a sewing-needle. The space which is left in the vessel is filled up with charcoal-dust, which prevents it from losing the quality of steel, and preserves the heat long enough to give it the proper degree of pliancy.

As Messrs Mouchel always used iron and steel at the same manufactory, they have been able to reduce their operations to a general system; and to attain this end, have determined a graduated scale, by which the wire will not be more stretched in the drawing-plate in one number or size than another.

The following is the method they contrived, in order to form this scale for the iron-wire :—They take a certain quantity of various thicknesses, which has been drawn as fine as the iron would bear; the smallest size is 100,000 metres, (109,333 yards,) in length to the kilogramme, 2.2 pounds avoirdupois; they note the weight that each might be capable of supporting without breaking; this being expressed by figures, it is easy, by a few interpolations, to express them in a progressive form. This kind of scale has been partly formed by comparing the weight of the different sizes with equal lengths, from which gauges or calibres may be made for the use of the workman. These gauges are certain guides, which they cannot mistake, except through great carelessness. If they had not these gauges, they would often pass the wire through holes in the drawing-plates, that are too large for it, whence it does not acquire the strength it should have in proportion to its thickness, and loses its hardness ; they might also pass it through holes that were too small, which would weaken it, and render it very brittle. In the latter case it frequently happens that the steel of the drawing-plate, being unable to sustain the force to which it is exposed, will give way, as if the plate were too soft; and the wire will be brittle at the beginning, and soft and too thick at the other extremity.

The greatest part of the fine wire at Messrs Mouchel's manufactory is drawn by workmen who are dispersed about the country; but they have also a machine which moves twenty-four bobbins in a horizontal direction, which only requires the workmen to look after it. It is upon the bobbins that the wire is reduced to the different degrees of thinness desired ; therefore this is the last operation in the art of making iron and steel-wire, although it has all requisite qualities given to it in the workshop of the wire-drawer.

Wire is still incapable of being made into needles and carding-hooks until it has undergone another operation for dressing and straightening the wire, by which it is made to lose the bend or curve that it acquires on the bobbins.

This work consists in drawing the wire between pins fixed on a piece of wood, and which act to bend the wire, first in one direction and then in the opposite, in a waving line, of which the waves are at first larger, but decrease gradually, and the last bend of which tends to force the wire into a straight line. The dresser is obliged constantly to adjust the pins, by inclining or raising them with strokes of the hammer. Also, for each number of wires, the pins must be at different and calculated distances. This requires a workman of intelligence, diligence, and address.

An ingenious instrument is now appropriated to this operation, and removes all difficulty. Six little puppets of very hard steel are substituted for the nails of the ordinary instrument, and are fixed on parallel bars of metal, so jointed together that the movement of them all will be parallel, and the puppets are widened or brought nearer together by screws; the wire is drawn between these puppets in a zigzag or waving line, and the repeated flexures break the sinuosities of the wire. There is a conductor of the wire to the puppets, and another conductor which serves to prevent the wire from being shaken. There are slight grooves at the extremity of the puppets, to give a passage to the wire. A scale sustained by a screw indicates the distance at which the puppets should be placed from each other, to straighten each size of wire; this forms nearly an invariable rule, and the dresser saves a third of the time which is employed in regulating the pins of the instrument formerly used. There is nothing more to be done but to draw out the wire by means of a wheel, on which he reels it, and then form it into bundles to be delivered to the consumers.

The steel-wire of France is proper for many purposes. It is brought from Messrs Mouchel for making knitting-needles in the English fashion, shoemaker's needles, and other similar articles; it may be also used for needles of all sizes, and even for cards for wool-combing; but as this steel is much more expensive than the iron-wire, it is very seldom used for the latter purpose.

The method of preparing the draw-plates is described by Messrs Mouchel, and is different from that before described.

For making wire for cards, two sorts of drawing plates are used, large and small ones; the first, for the sort of wire that we have been describing, is drawn with the pincers, as fig. 359, and with the bobbin or roller, which is a cylinder, adapted to the axis turned by the water-mill, and is used in preference, to avoid the marks made on the wire by the pincers; the small drawing-plates are used for such wire as may be drawn by hand. The steel which they employ for these drawing-plates should never vary in quality, except that the smallest pieces are made of the finest steel. Several pieces of iron are disposed in the furnace in the form of a box without a lid, their weight being according to the use for which they are intended to be made. The workman fills each of these boxes with cast-steel, and having covered it over with a luting of clay, it is exposed to a fierce fire until the steel be melted. His art consists in seizing the proper moment to withdraw the plate from the fire; he raises the luting, and blows on it through a tube, in order to drive off all heterogeneous parts, and then amalgamates it with the iron by light blows; after it is cool, he replaces it at the fire, where the fusion again takes place, but to a less degree than before; he afterwards works the steel with light blows of the hammer, to purify and solder it with the iron. This operation is repeated from seven to ten times, according to its quality, which renders it more or less difficult to manage. During this process, a crust forms on the steel, which is detached from it the fifth time of its exposure to the fire, because this crust is composed of an oxydated steel of an inferior quality. It sometimes happens that two, and even three, of these crusts are formed of about two millimetres, or one-sixteenth of an inch, in thickness, which must also be removed.

After all these different fusions, the plate is beaten by a hammer wetted with water, and the proper length, breadth, and thickness are given to it. When thus prepared, the plates are heated again, in order to be pierced with holes by punches of a conical form; the operation is repeated five or six times, and the punches used each time are progressively smaller. It is of importance that the plate never be heated beyond a cherry-red, because if it receives a higher degree of heat, the steel undergoes an unfavourable change. The plates, when finished, present a very hard material, which nevertheless will yield to the strokes of the punches and hammer, which they require when the holes become too much enlarged by the frequent passing of the wire through them.

When the plates have been repaired several times, they acquire a degree of hardness which renders it necessary to anneal them, especially when they pass from one size to another; sometimes they do not acquire the proper quality until they have been annealed several times. Notwithstanding all the precautions which are taken in preparing the plates, the steel still varies a little in hardness, and according to this variation they should be employed for drawing either steel or iron-wire; and if the workman who proves them finds that they are too soft for either the sreel or iron, they are put aside, to be used by the brass-wire drawers.

A plate that is best adapted for drawing of steel-wire is often unfit for the iron; for the long pieces of this latter metal will become smaller at the extremity than at the beginning, because the wire, as it is drawn through the plate, is insensibly heated, and the adhering parts are swelled, consequently pressed and reduced in size towards the latter end. The plates that are fit for brass are often too soft for iron, and the effect resulting is the reverse of that produced by a plate that is too hard.

The smallest plates which Messrs Mouchel use are at the least two centimetres, or eight-tenths of an inch in thickness, so that the holes can be made sufficiently deep; for when they are of a less thickness, they will seize the wire too suddenly, and injure it.

This inconvenience is much felt in manufactories where they continue to use the plates for too long a time, as they become exceedingly thin after frequent repairs. One of Messrs Mouchel's large plates reduces 1,400 kilogrammes, (3,080 lbs. avoirdupois,) from the largest size of wire to N° 6, which is of the thickness of a knitting-needle; 400 kilogrammes, (880 lbs.) of this number are afterwards reduced in one single small plate to N° 24, which is carding-wire; and to finish them, they are passed through twelve times successively.

Wires are frequently drawn so fine as to be wrought along with other threads of silk, wool, or hemp; and thus they become a considerable article in the manufactures.

Dr Wollaston, in 1813, communicated to the Royal Society the result of his experiments in drawing wire. Having required some fine wire for telescopes, and remembering that Muschenbroeck mentioned wire, 500 feet of which weighed only a single grain, he determined to try the experiment, although no method of making such fine wire had ever yet been published. With this view, he took a rod of silver, drilled a hole through it only one-tenth its diameter, filled this hole with gold, and succeeded in drawing it into wire till it did not exceed the three or four thousandth part of an inch, and could have thus drawn it to the greatest fineness perceptible by the senses. Drilling the silver he found very troublesome, and determined to try to draw platina-wire, as that metal would bear the silver to be cast round it. In this he succeeded with greater ease, drew the platina to any fineness, and plunged the silver in heated nitric acid, which dissolved it, and left the gold or platina wire perfect.

LEAD MANUFACTURE.

Lead ore is found in most parts of the world. In Britain the principal lead-mines are situated in Cornwall, Devonshire, and Somersetshire; in Derbyshire, Durham, Lancashire, Cumberland, and Westmoreland; in Shropshire, Flintshire, Denbighshire, Merionethshire, and Montgomeryshire; at the lead-hills in Scotland, on the borders of Dumfrieshire and Lanarkshire, in Ayrshire, and at Strontian in Argyleshire.

The smelting of the ore is performed by either a blast-furnace, called an ore-hearth, or a reverberatory-furnace. In the former method, the ore and fuel are mixed together, and exposed to the action of the blast, which quickly fuses the metal, and causes it to fall into the lower part of the hearth, where it is protected from the oxygen of the blast by the scoria that floats upon its surface.

When the fluid lead is tapped, or drawn off, a sufficient quantity of it is left in the furnace to float the liquid scoria; but when the whole of the lead is to be drawn off, the blast is stopped, and some lime is thrown into the furnace to concrete the scoria, while the lead is run out.

In smelting by the reverberatory-furnace, which is undoubtedly the best in places where there is an ample supply of coal, the fire is made at one end, and the flame passes over the hearth, and enters into an oblique chimney, which terminates in a perpendicular one, called a stack, of considerable height. The length of the hearth, from the place where the fire enters to the chimney, is about eleven feet, two of which constitute the throat of the furnace; the remainder forms a concave surface, four and a half feet wide at the throat of the furnace, seven feet four inches at the distance of two feet from the throat, seven feet two inches in the middle of the hearth, five feet eleven inches at two feet distance from the chimney, and two feet ten inches where the flame enters the chimney at two apertures, each ten inches square; the throat of the furnace is two feet long, four feet wide, and six inches deep; the length of the fire-place four feet, equal to the width of the throat; its width two feet, and depth three feet, from the grate up to the throat of the furnace; the section of the oblique chimney is sixteen inches square, and of the perpendicular twenty inches, supposing a straight horizontal line drawn from the lower plane of the throat of the chimney to the opposite side of the furnace; the lower part of the concave hearth, which is in the middle of this cavity, is nineteen inches below this line, the roof of the furnace being seventeen inches above the same line; the rest of the hearth is conformably concave.

The furnace on one side has three openings, about ten inches square, at equal distances from each other, and provided with iron doors, which can be removed as occasion may require. Besides these apertures, which are for the purpose of raking and stirring the ore, &c. and consequently, upon a level with the horizontal line above alluded to, there are two others of smaller dimensions, the one to tap the liquid lead, the other the scoria. The ore is introduced by a vessel in the shape of a hopper placed in the roof of the furnace.

The ores of lead, similarly to those of iron and most other metals, are combined with various kinds of earthy matter, which requires them to be well pounded before they are introduced into the reverberatory or smelting furnace. The pounding is sometimes performed by women using hammers, and sometimes the ores are pounded or crushed by causing them to pass through iron rollers loaded with great weights. After the ores have been pounded or crushed, the earthy matter is separated by washing.

The powder to be washed is put into a riddle or sieve, and placed in a large tub full of water; when, by a certain motion, the lighter or earthy parts are separated and thrown over the edge of the riddle, while the metal, which, as we have before stated, is always considerably heavier than its accompanying ingredients, is retained. There are some impurities, however, which cannot be separated by this process, consisting principally of *blind*, or *black-jack*, called *mock* ore, and pyrites, or sulphuret of iron, named *Brazil.*

In the process of smelting, the ore is spread upon the concave hearth, so that the flame may act upon it, and release the sulphur. When the sulphur has escaped, the lead combines with oxygen, and the oxyd of lead, thus formed, combines with and reduces the earthy matter to a liquid, which floats upon the surface of the metal, and for the remainder of the operation, protects from the action of the oxygen. The temperature of the furnace is now considerably raised, to separate as quickly as possible the lead from the liquid scoria; after which a considerable portion of the scoria is tapped off, leaving only so much behind as is necessary to protect the metal from the action of the oxygen. The fire is now slackened, and a quantity of slack, or refuse pit-coal, thrown into the furnace, which serves to diminish the heat, and to concrete the melted scoria; though this last part of the process is not well done unless powdered lime be also added. The scoria being now hardened, is broken to pieces by a rake, and thrust to the opposite side of the furnace, where it is taken out through the apertures already mentioned.

The lead is now tapped, in a manner similar to that described in the manufacture of iron, and is allowed to run into a large iron pan, from whence it is laded into moulds to cast into pigs. When the ores abound with blind, or black-jack, or sulphate of iron, it becomes necessary to add the fluat of lime, as a flux.

The scoria is still found to contain some lead, independent of that in the state of oxyd, and chemically combined with it, and is consequently exposed to the heat of another furnace, being a species of blast, and called a slag-hearth, which fuses the scoria, and causes the metal to penetrate through it, and fall into a cavity, where it is protected from the agency of the blast, and from whence it is taken and cast into pigs.

As all lead ores contain more or less of silver, we shall extract from Dr Rees's Cyclopædia the method by which the silver, by the oxydation of the lead, is extracted.

" A shallow vessel, or cupel, is filled with prepared fern-ashes well rammed down, and a concavity cut out for the reception of the lead, with an opening on one side for the mouth of the bellows, through which the air is forcibly driven during the process. The French smelters cover the surface of the ashes with hay, and arrange symmetrically the pieces of lead upon it. When the fire is lighted, and the lead is in a state of fusion from the reverberation of the flame, the blast from the bellows is made to play forcibly on the surface, and in a short time a crust of yellow oxyd of lead, or litharge, is formed and driven to the side of the cupel opposite to the mouth of the bellows, where a shallow side or aperture is made for it to pass over; another crust of litharge is formed and driven off, and this is repeated in succession till nearly all the lead has been converted into litharge and driven off. The operation continues about forty hours, when the complete separation of the lead is indicated by a brilliant lustre on the convex surface of the melted mass in the cupel, which is occasioned by the removal of the last crust of litharge that covered the silver. The French introduce water through a tube into the cupel, to cool the silver rapidly, and prevent its spirting out, which it does when the refrigeration is gradual, owing probably to its tendency to crystallize. In England the silver is left to cool in the cupel, and some inconvenience is caused by the spirting, which might be avoided by the former mode.

" The silver thus extracted is not sufficiently pure; it is again refined in a reverberatory-furnace, being placed in a cupel lined with bone-ashes, and exposed to greater heat; the lead which has escaped oxydation by the first process, is converted into litharge, and absorbed by the ashes of the cupel.

" The last portions of litharge in the first process are again refined for silver, of which it contains a part which was driven off with it. The litharge is converted into lead again by heating it with charcoal; part is sometimes sold for pigment, or converted into red-lead. The loss of lead by this process differs considerably, according to the quality of the lead.

The litharge commonly obtained from three tons of lead amounts to 58 hundred weight; but when it is again reduced to a metallic state, it seldom contains more than 52 hundred weight of lead, the loss on three tons being eight hundred weight. The Dutch are said to extract the silver from the same quantity of lead with only the loss of six hundred weight."

Having explained the process by which pig-lead is extracted from the ores, it now remains for us to show the methods by which pig-lead is manufactured into sheet-lead, or into the tubes called lead pipes.

In the manufacture of sheet lead, the ingots or pigs are put into a large caldron or furnace built with free-stone and earth. Near this furnace is the table or mould on which the sheet is to be cast; it is made of large pieces of wood, well jointed, and bound at the ends with bars of iron, and has a ledge or border of wood, about two or three inches thick, and one or two high, called the *sharps*. The tables are usually about three or four feet wide, and from eighteen to twenty feet long. The table is covered with very fine sand, which is prepared for the casting by moistening it with clear water, working it together with a stick, beating it flat with a mallet, and smoothing it with a piece of brass or wood.

A long narrow piece of wood, with notches cut in each end so as to fit the ledges, is placed over the table, and is so arranged, that the space between it and the sand shall be proportionate to the intended thickness of the plate. The workman gradually slides the strike from one end of the table to the other, by which means he obtains a sheet of the requisite, and in all parts of equal, thickness.

At the top of the table is a large triangular iron peel or shovel, with its fore part bearing upon the edge of the table, and the hinder part on a tressel, somewhat lower than the table; the design of which is, to prevent the liquid metal running off at the fore side, where there is no ledge. The metal being sufficiently fused, is taken out of the furnace or caldron with a large iron ladle, and is put into the peel, where it is cleansed of its impurities by using another large iron ladle pierced like a scummer. The handle of the peel is now raised, which causes the liquid metal to run into the mould, while the workman, with the strike, regulates the thickness. When the sheet is of the required thickness, the handle of the peel is lowered, and the sheet is allowed to cool. When set, the edges on both sides are planished, in order to render them smooth and straight.

The method above described is only used in casting large sheets of lead; in casting sheets of smaller dimensions, the table or mould, which is placed in an inclined position, is, in lieu of sand, covered with a piece of woollen stuff nailed down at both ends, and over that is placed a very fine linen cloth.

In this process great attention must be paid to the heat of the liquid metal, and a piece of paper is used as a test; if the paper take fire, the lead is too hot, and would destroy the linen; if it be not shrunk and scorched, it is not hot enough.

When the sheets are required to be very thin, it is necessary to make the peel and strike of one piece. It is a kind of wooden box without a bottom, being closed only on three sides; the back of it is about seven or eight inches high, and the two sides, like two acute angles, diminish to the top; the width of the middle makes that of the strike, which again makes that of the sheet to be cast.

The strike is so placed, that the highest part is towards the lower, and the two sloping sides towards the upper end of the table. The top part of the table, where the metal is poured in, is covered with a pasteboard, which serves as a bottom to the case, and prevents the linen from being burnt while the metal is pouring in.

The strike or peel being filled with lead, according to the intended size of the sheet, two men, one at each side, seize hold of it, and with greater or less velocity, as the sheet is to be more or less thick, force it down the inclined table; for the thickness of the sheet always depends upon the velocity with which the strike slides down the table. The sheet-lead, after casting, is frequently reduced by rollers.

As this particular department is so intimately connected with the business of a plumber, we shall not be considered as departing from the subject by inserting the following tables, from *Hutton's Mensuration.*

Plumber's work is commonly estimated by the pound or hundred weight; but the weight may be discovered by the measure of it, in the manner below stated. Sheet-lead used in roofing, guttering, &c. is commonly between seven and twelve pounds weight to the square foot; but the following table shows by inspection the particular weight of a square foot for each of several thicknesses.

Thickness.	Pounds to a square foot.	Thickness.	Pounds to a square foot.
.10	5.899	.15	8.848
.11	6.489	.16	9.438
$\frac{1}{9}$	6.554	$\frac{1}{6}$	9.831
.12	7.078	.17	10.028
$\frac{1}{8}$	7.373	.18	10.618
.13	7.668	.19	11.207
.14	8.258	$.2=\frac{1}{5}$	11.797
$\frac{1}{7}$	8.427	.21	12.387

In this table the thickness is set down in tenths and hundredths, &c. of an inch; and the annexed corresponding numbers are the weights in avoirdupoise pounds and thousandth parts of a pound. So the weight of a square foot of $\frac{1}{10}$ or $\frac{10}{100}$ of an inch thick is 5 pounds and $\frac{899}{1000}$ of a pound; and the weight of a square foot to one-ninth of an inch thickness is 6 pounds and $\frac{554}{1000}$ of a pound. Lead pipe of an inch bore is commonly 13 or 14 pounds to the yard in length.

EXAMPLES:

1. How much weighs the lead which is 39 feet 6 inches long, and 3 feet 3 inches broad, at 8½ lbs. to the square foot?

Decimals.

39.5
$3\frac{1}{4}$
118.5
9.875
128.375
$8\frac{1}{2}$
1027.000
64.1875
1091.1875

Duodecimals.

39. 6
3. 3
118. 6
9.10.6
128. 4.6
$8\frac{1}{2}$
1024
64
$2\frac{5}{6}$
$0\frac{17}{48}$
Answer . . . $1091\frac{9}{48}$ lbs.

2. What cost the covering and guttering of a roof with lead, at 18*s.* per cwt.; the length of the roof being 43 feet, and the breadth or girth over it 32 feet, the guttering 57 feet long, and 2 feet wide; the former 9,831 lbs. and the latter 7,373 lbs. to the square foot?—Answer, 115*l.* 9*s.* 1½*d.*

It is now time to direct our attention to the manufacture of *lead pipes*, which are universally employed for small water-pipes, from the facility of bending them in any direction, and soldering their joints.

Lead pipes are sometimes cast in an iron mould, made in two halves, forming, when put together, a hollow cylinder, of the size of the intended pipe; in this cylinder, or mould, is put an iron rod or core, extending from the top to the bottom, and leaving all round a space between it and the cylinder of the intended thickness of the pipe. The lead is poured in at a spout, formed by two corresponding notches cut in each half of the mould; and a similar hole is made at another place for the escape of air. The mould is fastened down upon a bench, upon which, at one end, and in a line with its centre, is a rack, moved by toothed-wheels and pinions.

When the pipe is cast, a hook at the end of the rack is put into an eye at the end of the iron core, which, by the action of the cog-wheels and pinions, is drawn so far out, that about two inches of it only remain in the end of the pipe; the two halves of the mould, which fasten together by wedges or screws, are now separated from the pipes, and are fastened upon the iron core, and the two inches of lead pipe attached to it; melted lead is again poured into the mould, which, uniting with the end of the first piece, forms the pipe of considerable length; and the operation is repeated till it be of the length required.

Another and a much better method is, to cast the lead in an iron mould upon a cylindrical iron pipe, of a size proportioned to the bore of the pipe to be made, and leaving a space between the core and the mould three or four times the thickness of the intended pipe, and in short lengths, which are afterwards drawn through holes in pieces of steel, similar to the process of wire-drawing, till the pipe is reduced to the required thickness.

Another method is that for which the celebrated iron-manufacturer, Mr John Wilkinson, of Brosely, took out a patent in 1790, and which, since the expiration of his patent, has been successfully practised by many other manufacturers. This method consists in casting a circular piece of lead, about eighteen inches long, with a core or hole longitudinally through its centre. This piece is of considerably larger diameter than that of the pipe intended to be made. The core or hole at one extremity suddenly decreases, so as to form on the internal surface of the piece of lead a stop or shoulder, against which a polished iron triblet or mandrel, which has been passed thus far along the core, rests. This triblet or mandrel is of somewhat greater length than the length required of the pipe to be manufactured, which, generally speaking, is from seven to nine feet. An iron screw, having a loop at the opposite end, is then passed down the other end of the core, and is screwed into that part of the mandrel which rests against the shoulder. In this state the mandrel, with the circular piece of lead fixed fast on it, is taken to the drawing-table.

The drawing-table, in the principle of its operation, resembles the block described in the Wire Manufacture in every respect, though it is far more powerful. The table generally used is about thirty feet long, by two feet wide; having at one end a powerful cylinder with a chain attached to it. This cylinder receives motion from a steam-engine, or other first mover, and can be thrown in and out of geer by an adaptation of any one of the appropriate modes described under the article "Mill-geering." About two-thirds the length of the bench from the cylinder, or roller, are two pins or stops to hold a steel plate, which has a gradation of conical holes. Through the largest of these holes, which is somewhat less than the diameter of the circular piece of lead, the loop that is screwed on to the end of the mandrel is passed, and attached to a hook at the extremity of the chain, which chain is affixed to the cylinder or roller. The cylinder being now thrown into geer, the piece of lead is drawn through the hole in the steel plate, which diminishes it in diameter, and increases it in length; and this operation is carried successively through the series of gradually decreasing holes in the draw-plate, until the pipe is reduced to the required diameter. The cylinder is now struck out of geer, and the mandrel liberated from the chain, which is immediately attached to the other end of it. The steel draw-plate being now removed, the stops against which it rested allow the mandrel to pass between them, but detain the lead pipe, which, consequently, by striking the cylinder into geer, allows the mandrel to be extricated from it. A small portion of pipe being cut off at both ends, the pipe is considered finished. Through the whole of the operation, great care is taken to keep the mandrel and steel plate well oiled.

As no acid can pass through lead pipe without becoming more or less affected by its deleterious qualities, it is necessary, in cases where acids are used, to have pipes made of iron, or of lead lined with tin. To line lead pipe with tin, the lead pipe must be cast in a vertical mould, which has a core of somewhat larger diameter than the intended bore of the pipe passing down its centre. When the pipe is cast, and the metal is set, this mandrel is drawn out of the mould, and another of smaller diameter is substituted. About as much coarse resin as will lay on a shilling is now thrown into the space between the pipe and the core or mandrel just passed down the mould. This resin by the heat of the lead is melted, and runs to the bottom of the mould. The melted tin being now poured in, the resin will float on its surface, and, consequently, as the tin rises, anoint the tin in every part, and act as a flux, and unite the two vessels. As soon as the tin is set, the last-mentioned mandrel is drawn out, and the external mould being removed, the lead now lined with tin is, when quite cold, ready to be submitted to the process of drawing. Various other equally simple processes are adapted to this purpose.

PAPER MANUFACTURE.

Paper, that highly valuable substance, which enables us to communicate our thoughts to persons situate at the most distant quarters of the civilized globe, is manufactured from rags, by the aid of machinery.

It was formerly necessary to assort with great care the rags which were intended to be manufactured into paper; and none but the whitest and best, and which, consequently, were the most expensive, could be made into paper of the finest quality; but since the introduction of chlorine, (which was discovered by Scheele,) into our bleaching establishments, the necessity of this assortment has been greatly obviated; as it was soon conceived that that chemical agency, which was capable of bleaching linen, was also applicable to the whitening of the rag during the process of paper-making.

At that period of the process, when the rag is coming into a state of pulp, chlorate of lime, which was first manufactured by Mr Tennant, of Glasgow, is introduced into the vat; and, by its chemical action on the fibre, whitens or bleaches the whole mass; thus enabling the manufacturer to produce a whiter and much finer quality of paper from rags of a secondary quality, than he had heretofore done from rags of the most expensive description. It must, however, be admitted that, as in all bleaching processes where the fibre is more or less deteriorated by the action of chlorine, the paper manufactured and whitened by this agent is not so strong as that formerly produced; as may be observed in some thick and beautifully white papers frequently offered to the public at astonishing low prices, which are manufactured from coloured and inferior rags, with a superabundance of the chlorate of lime introduced in the process of the manufacture. By this, therefore, it is evident that the chlorate of lime, when used too abundantly, will rot or destroy the fibre of the whole; but when judiciously applied, it produces a paper of superior colour, and of adequate strength for all practical purposes.

The paper-mill consists of a water-wheel, or other first mover, connected with a combination of toothed and other wheels, so arranged as to cause the cylinder in the *washer*, and the one in the *beating* engine, which will be hereafter described, to make from 120 to 150 revolutions per minute. On the same shaft, and of the same size as the water-wheel, is a toothed or cogged-wheel, which plays in a pinion; the spindle of this pinion is furnished with a crank, which, by means of a connecting rod, gives a reciprocating motion to a lever, for the purpose of working two pumps, which raise a constant stream of water from the mill-dam. This stream of water is kept running through the rags in the washing-engine, to carry away the dirt separated from them by the operation. The structure of an engine is more minutely explained by figs. 371, 372, 373, 374, &c.; fig. 371 being a section through the length of the engines, and fig. 372 a horizontal plan.

The large vat or cistern, A A, is of an oblong figure on the outside, the angles being cut off; but the inside, which is lined with lead, has straight sides and circular ends. It is divided by a partition, B B, also covered with lead. The cylinder C is fixed fast upon the spindle D, which extends across the engine, and is put in motion, as before described, by the pinion E, placed on the extremity of it. The cylinder is made of wood, and furnished with a number of teeth, or cutters; fixed fast on its circumference, parallel to the axis, and projecting about an inch, as is shown on a larger scale at fig. 375.

Immediately beneath the cylinder, a block of wood, H, is placed, and provided with similar cutters to those of the cylinder, which, when they revolve, pass very near the teeth of the block, but do not touch; the distance between them being capable of regulation, by elevating or depressing the bearings on which the necks D, D, of the spindle are supported. These bearings are made on two levers, F, F, which have tenons at their ends, fitted into upright mortises, made in short beams, G, G, bolted to the sides of the engine. (See also fig. 373.) The levers, F, F, are movable at one end of each, the other ends being fitted to rise and fall on bolts, in the beams G, as centres.

The front one of these levers, or that nearest to the cylinder C, is capable of being elevated or depressed, by turning the handle of the screw *b*, which, as shown in fig. 373, acts in a nut *a*, fixed to the tenon of F, and comes up through the top of the beam G, upon which the head of the screw

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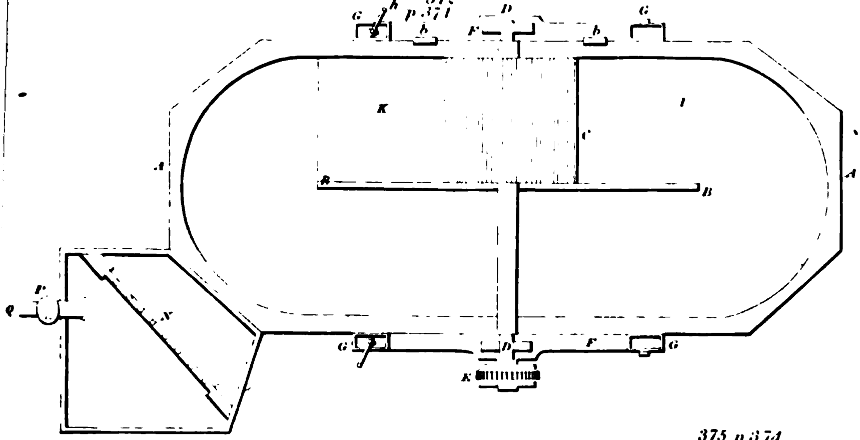
Pl. 50 51 & 52

From 371 to 375

372 p 371



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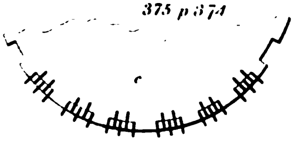
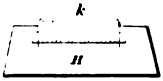
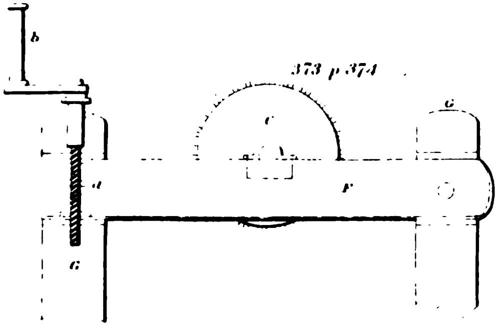
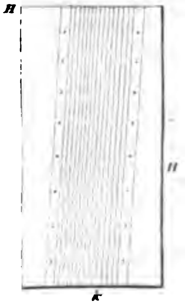




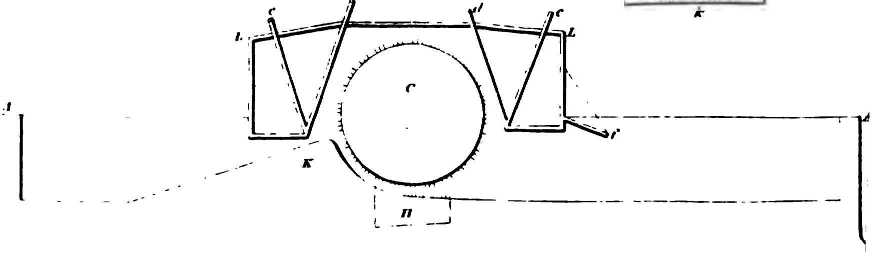
373 p 374



374 p 375



371 p 375



takes its bearing. Two brasses are let into the middle of the levers F, F, and form the bearings for the spindle of the engine to work upon. The screw, *b*, is used to raise or lower the cylinder, and cause it to cut finer or coarser, by enlarging or diminishing the space between the cutters in the block, and those of the cylinder.

Near K, figs. 371 and 372, is a circular breasting made of boards, and covered with sheet-lead: it is curved to fit the cylinder very truly, and leaves but very little space between the teeth and breasting. An inclined plane, K, leads regularly from the bottom of the engine-vat to the top of this breasting; and at the bottom of it the block, H, is fixed.

The engine is supplied with water by a pipe, Q, bringing it from the pump; this pipe delivers it into a small cistern, M, adjoining, and communicating with the engine. The pipe has a cock, P, to stop the entrance of the water, when required, or to regulate the quantity of its discharge. The small cistern has a grating fixed across it, covered with a hair-strainer, to catch any extraneous matter which may come in with the water, or a flannel bag is sometimes tied over the orifice of the cock, P, through which all the water must be filtered. When the engine is filled with water, and a quantity of rags put in, they are, by the revolution of the cylinder, drawn between its cutters and the teeth of the block H. This cuts them in pieces, then, by the rapid motion of the cylinder, the rags and water are thrown over the top of the breasting, upon the inclined plane; in a short time this raises more rags and water into that part of the engine-vat; and the tendency to restore the equilibrium puts the whole contents of the vat in slow motion, down the inclined plane K, and round the partition B B, by which they come to the cylinder again in about the space of 20 minutes; so that the rags are repeatedly cut and chopped in every direction, till they are reduced to a pulp.

This circulation is of advantage, in turning the rags over in the engine, and causes them to present themselves to the cutters in a different direction every time; for as the cylinder cuts or clips in straight lines; in the same manner as a pair of shears, it is requisite to cut the rags across in different directions, to reduce them to a pulp.

The manner of the cutting is this: the teeth of the block are placed rather inclined to the axis of the cylinder, as shown by fig. 374, but the teeth of the cylinder are parallel to its axis; therefore, the cutting edges, when they meet, are at a small angle, and come in contact first at one end, and then successively the contacts proceed along to the other end, so that any rags interspersed between them are cut in the same manner as they would be between the blades of a pair of shears. Sometimes the plates or cutters, *k*, in the block, are bent to an angle in the middle, instead of being straight, and inclined to the cylinder; in this case, they are called elbow plates, and of course the two ends are both inclined to the axis of the cylinder in opposite directions. In either case, the edges of the plate of the block cannot be straight lines, but must be curved, to adapt themselves to the curve which a line traced on the cylinder will of course have.

The plates or cutters of the block are united, by screwing them altogether, and fitting them into a cavity cut out in the wooden block H; their edges are bevelled away on one side only, as shown at *k* in the section, fig. 374. The block is fixed in its place by being made dove-tailed, and truly fitted into the bottom of the cistern, so that the water will not leak by it. The end of it comes through the wood-work of the chest, and projects a small distance on the outside of it, being kept up to its place by a wedge, so that by withdrawing this wedge, the block becomes loose, and can be removed, to sharpen the cutters, as occasion requires. This is done on a grindstone, the plates being first separated from each other.

The cutters of the cylinder are fixed into grooves, cut in the wood of the cylinder, at equal distances from each other round its circumference, in a direction parallel to its axis; the number of these grooves is twenty; and for the washer, each groove has two cutters or bars put into it; then a fillet of wood is driven fast in between them, to hold them firm; and the fillets are kept fast by spikes driven into the solid wood of the cylinder. The beater is made in the same manner, except that each groove contains three bars and two fillets, as shown in fig. 375.

In the operation of the cylinder, it is necessary that it should be enclosed in a case, or its great velocity would throw all the water and rags out of the engine. The case is a wooden box, L L, enclosed on all sides except the bottom; one side of it rests upon the edge of the vat, and the other upon the edge of the partition B B. The lines, *c c*, represent the edges of wooden frames, which are covered with hair or wire-cloth; and immediately behind these, the box is made with a bottom, and a ledge towards the cylinder, which makes a complete trough.

The dark spaces, *e e*, in fig. 371, show the situation of two openings, or spouts, through the side of the case, which lead to flat lead-pipes, *b*, *b*, fig. 372, which are placed by the side of the vat; the beam, F, being cut away for them. They are waste-pipes, to convey away the foul water from the engine; for the cylinder, as it turns, throws a great quantity of water and rags against the sieves: the water goes through them, and runs down into the trough at *e e*, and from thence into the ends of the lead-pipes, *b b*, fig. 372, by which it is conveyed away; *d*, *d*, fig. 371, are grooves for two boards, which, when put down in their places, cover the hair-sieves, and stop the water from going through them, if it is required to retain the water in the engine. This is always the case in the beating-engines, and therefore they are seldom provided with these waste-pipes, or at most on one side only; the other side of the cover being curved, to conform to the cylinder. Except this, the only difference between the washing-engine and the beater is that the teeth of the latter are finer, having 60 instead of 40 bars on its circumference; and it revolves quicker than the washer, so that it will cut and divide those particles which pass through the teeth of the washer.

The rags being now reduced to a state of pulp, we shall in the next place proceed to show the method of forming it into sheets of paper.

It was formerly the custom to allow a small, but sufficient portion of the pulp to flow on a sieve furnished with two handles, which sieve was agitated by a workman until the pulp had subsided or settled regularly throughout the surface. This, when it had passed through the usual processes of pressing, drying, &c. constituted a sheet of paper; and its texture was indicated by the fineness of the quality of the wire out of which the sieve was constructed.

This unmechanical and desultory mode of operation has been obviated by improvements effected by many ingenious persons; but the machines which are now almost universally employed, and which have most decidedly superseded all other attempts at the same object, was the invention of the Messrs Fourdrinier. The action and arrangement of this ingenious piece of mechanism consists in having a horizontal frame, of any required length, furnished with a roller or cylinder at each end, over which is stretched an endless web of brass wire, of the requisite texture or fineness for the paper about to be manufactured. At one end of the frame, parallel with, and immediately over, one of the cylinders, is a long angular trough, into which the pulp is received, whence it issues through a long slit or opening, which is regulated by a screw, and falls on the surface of the web beneath. At this period of the process, the cylinders are set in motion, and the web proceeds slowly forward with a tremulous motion, which arranges and disperses the pulp regularly over the whole surface of the web. This tremulous motion is imparted to the whole of the machinery by an eccentric movement.

As soon as the paper arrives in this crude and wet state at the extremity of the web of the further cylinder, it is wiped and taken up by a larger cylinder, covered with felt or flannel, and is passed between a series of similar cylinders, and finally delivered to a reel, and wound off in a coil or hank so long as the operation proceeds. Thus, paper, by the action of this ingenious machine, may be manufactured to an unlimited length, and of any width that is compatible with the manufacture of wire web. The reel or winder being now withdrawn, the coil of paper is cut on both sides, forming sheets of the length and breadth of the machine and reel on which it is wound.

The arrangement of the different speeds of the various cylinders for moving the web, and afterwards pressing the paper, together with the action of the reel, and the tremulous motion that is imparted to the whole of the machinery by the eccentric or wiper, as also the regular supply of the pulp for the various qualities of the paper to be manufactured, form a most elegant combination of ingenuity and mechanical knowledge; and it is only to be lamented that the inventors and first proprietors, of this great source of national industry, should not have obtained a reward adequate to the benefit which they have conferred on their country.

The quantity of water which a paper-mill can command to turn its engines, generally limits the extent of its trade; hence the manufacturers should attend to every improvement of the machinery which can increase their effect.

A very large and capital paper-mill, at Maidstone, in Kent, which is the principal seat of the paper trade in England, is worked by steam engines, and is found to answer very well. The machinery and building of a paper-mill should be well made, and firmly put together, otherwise its great velocity and power produces a tremor, which in time shakes every thing to pieces. The noise and vibration of a washing-engine is tremendous; for when it revolves 120 times per minute, and has forty teeth, each of which passes by twelve or fourteen teeth in the block at every revolution, it will make near 60,000 cuts per minute, and each of them sufficiently loud to produce the most horrible growling sound which can be conceived.

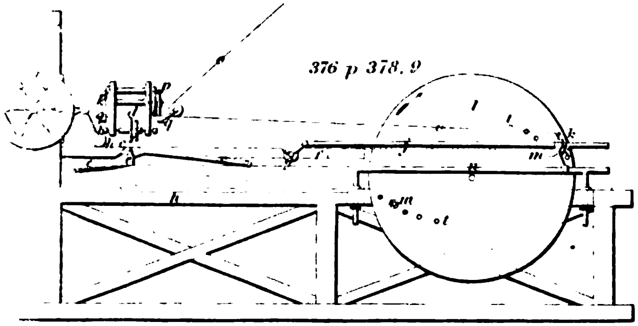
The beater revolving quicker, having sixty teeth, and twenty or twenty-four cutters in the block, will make 180,000 cuts per minute, which is so rapid, as to produce a coarse musical note or humming, which may be heard at a great distance from the mill. This great number of cuts will account for an engine being able, in the course of four or five hours' working, to reduce a quantity of rags to those exceedingly minute filaments of which paper is composed.

Mr John Dickenson took out a patent in 1809, for certain improvements on his former patent machinery for cutting and planing paper, as also for certain machinery for the manufacture of paper by a new method. His description of it is as follows:

The first part of the invention, consisting in certain improvements in the patent machinery for cutting and planing paper, is described in the annexed drawings; wherein fig. 376 represents a sectional elevation, fig. 377 a plan, and fig. 378 a transverse section. Every part in the elevation, fig. 376, is on a line with the same part in the plan, fig. 377, and the same parts are represented by the same letters in all the three figures; *a* is a reel, covered with paper; *b* a swinging roller, to draw the end of the paper a little back after it has been cut; *c* a bar, having a groove in its upper surface, into which the circular cutter *d* runs. The bar *c* is movable up to a certain height, and connected with two arms, *x x*, by means of which it may be moved downwards; the springs *e e* will elevate it again when the pressure is removed from the arms *x x*; *f* is a sliding frame, having a pair of tongs attached to the front of it, and marked *g*. The board on which the paper is laid is marked *h*; and on the side next the tongs is furnished with thin teeth, *i i*. The frame *f*, which carries the tongs, slides in grooves in the frame of the machine, and is moved backwards and forwards by the rod *j*, which in drawing the tongs from the reel of paper closes them; and in forcing them back again towards the reel of paper, opens them. On each side of the frame *f* is fixed a small roller, which act upon the arms *x x*, so that the frame in being forced towards the reel of paper presses the arms down, and consequently moves the bar *c* down out of the way of the tongs, which at that period are open. The end of the paper is at that time lying even with the extremity of the teeth *i i*, and the jaws of the tongs closing

PAPER MANUFACTURE

From 376 to 380 & 384 to 386



376 p 378, 9

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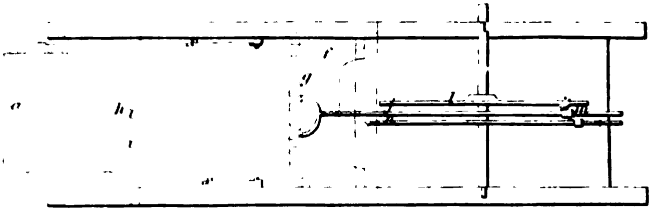
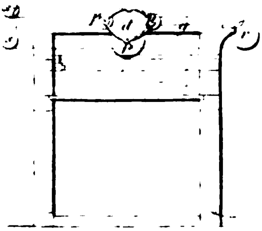
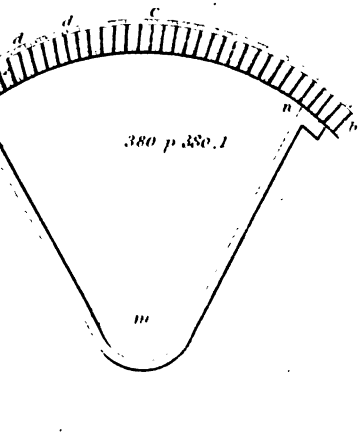


379 p 3

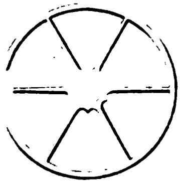
378 p 378



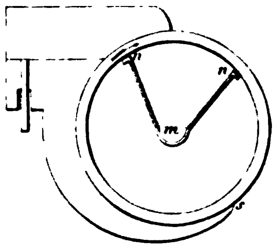
380 p 380.1



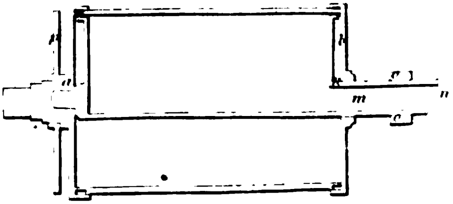
386 p 382



384 p 381



385 p 381



immediately that the rod *j* is put in motion to draw the frame back, seize the paper in every interval between the teeth, and draw it along with them. When they have carried it out the length that the sheet of paper is wanted, the bar *c* having been raised up to its place by the springs *e e*, the circular cutter is thrown across, and as the edge descends into the groove about the sixteenth part of an inch, the paper which is lying upon it is cut through, and the ends fall down upon the heap below the tongs; being then forced back, and at the same time opened by the rod *j*, the other end of the sheet is released, also the swinging roller *b* then falls down upon the board *h*, and draws back the end of the paper even with the line formed by the end of the teeth *i*, ready for being seized again by the tongs. The rods *j*, by which the frame carrying the tongs is moved backwards and forwards, has a hook *k*, which can be fixed at any part of the rod by a screw; and the clinck being furnished with pins *m m*, at two opposite points on its surface, these catch the hooks, and draw the rod, and consequently the frame, with the tongs outwards. When the clinck has made half a revolution, the hook is stopped by the bar *n*, and the rod and frame remain stationary while the paper is cut. When the pin has got clear of the hook, the rod and frame are immediately drawn back by a weight acting over a pulley, which is connected with the rod by the cord *o*. The circular knife is fixed in a sort of wagon, having four rollers *p p*, by means of which it runs along the beams *q q*. The knife is kept moving at the rate of about five hundred turns per minute, by means of a band passing round the small rigger *r*, and the pulleys *s s*, which is kept in motion by any convenient power. The wagon may be thrown across at the proper period by the following method, or any other more convenient. A cord is attached to the wagon, acting over a pulley with a weight at the end, sufficient to draw it across one way with a quick motion: for drawing it across the other way a cord is attached to the wagon, which is carried over a pulley, and fastened to the weight A, in fig. 379, which is much heavier than the weight before mentioned. The endless band B passes round the rigger D, which is kept in constant uniform motion, according to the rate at which the paper is cut. The band also passes round the rigger C, which has a click that stops it going round; consequently as the rigger goes on, it keeps winding up the weight A, and the spare band is engrossed by the smaller weight E, so that when the click that confines the rigger D is removed, the weight A descends and draws it round a complete revolution, when it is again caught by the click, at the same time the weight A draws the wagon across, and it is caught on that side the frame and confined by a click; when the next sheet is to be cut the wagon is released, and the weight attached to it on the other side draws it across again, the heavier weight A being by that time drawn up high enough to allow of its going all across; the two clicks may be contrived according to any common well-known mechanical method, and the motion that releases them can be communicated with the most advantage from the click *e*; the pins *m m* can be fixed in holes *t t* at a greater or less distance from the centre, according to the size the paper is intended to be cut, and the hook on the rod *j* must be shifted accordingly. A regular motion may be given to the click by any convenient power, and at such a rate as it is required to cut the paper.

The remainder of the drawings is for the purpose of explaining the remaining part of the invention, consisting of certain machines or machinery for the manufacture of paper, by a new method. For this purpose, a cylinder is constructed so as to possess the following requisites: in the first place it must be hollow and open at the ends; secondly, the surface of the periphery must be like a sieve, with apertures communicating with the internal part large enough to permit the passage of water, but calculated to intercept fibres of rag; thirdly, it must be so contrived that the surface will not yield from its perfectly cylindrical form, notwithstanding a very considerable degree of pressure upon it; fourthly, it must be furnished with broad flat rings for the purpose of covering part of its surface; at the ends there may be several pairs of these rings of different widths, in order to vary the proportion of the surface which is left uncovered, provided the same cylinder is extended for making different sized papers; fifthly, it must be hung upon an axis in a horizontal position, and firmly fixed in bearings, so that it may be turned by any convenient power; sixthly, the numerous small apertures on the external surface must open into a less number of large ones, communicating with the internal surface, with solid interstices between them; seventhly, it ought not to be made of wood, because it would be liable to warp, nor of iron, because it would rust, and injure the paper; brass or any other strong metal would be found most convenient. To construct a cylinder possessing the requisites above-mentioned, of which the dimensions must be according to the size and thickness of the paper it is intended, for making the patentee takes a brass cylinder, perfectly smooth inside and outside, excepting a small portion at each end, which is left plain, and turns the outside so as to resemble a screw, the threads of which are about a quarter of an inch apart, and the twenty-fifth part of an inch in depth, with a round edge. He then drills holes between the threads, which are cut in a taper form, the diameter at top being the width of the interval between the threads, and at the bottom reduced to one-half that size; the space on the outer surface of the cylinder, left between these holes on each side, is equal to the breadth of the thread; notches are cut in the threads for the purpose of letting in cross wires, the diameter of which is equal to that of the threads, so that when they are laid into the notches and soldered, or otherwise fastened down, the surface of the cylinder will resemble net-work, with openings of an oblong shape, and having the surfaces of all the interstices plane with each other, and wound to an equal curve. It is then covered with an endless web of woven wire, which is drawn tight over it. The ends of the cylinder are cut down, or rabbeted, so that a ring may be made to slide on each end; and the ends of the wire are fastened to this ring by means of small plates, which are put over the wire, and screwed down upon the rings by means of screws which pass through the wire. These rings are also furnished with other screws for the purpose of extending them out from the cylinder, and the wire being fastened to them, it is by that means stretched and drawn tight down upon the surface of the cylinder.

In the annexed drawing, fig. 380, *a* to *b* represents a transverse section of a segment of the cylinder, C C C being the holes; *d d d*, the cross wire; *e e e e*, the thread of the screw, which is shaded.

Fig. 381 is a plan of a portion of the external surface of the cylinder wherein A to B shows it without the cross wires, or the external wove wire; C C C are the holes, *e e e* the thread of the screw with the notches cut, *a a a*, for the reception of the cross wires; B to C shows it with the cross wires let in, *d d d*, which are soldered or otherwise fastened at their ends into the ends of the cylinder. C to D shows it with the woven wire laid over it, through which the the surface of the cylinder is seen underneath.

Fig. 382 is a section of a part of the cylinder at one end, where the holes are marked *c c c*, the cross wires *d d d*, the threads *e e e;* the external wove wire *f*, is represented by a red line, it is carried under the plates *g*, and fastened, by means of a number of screws, *h*, down upon the ring *i*, which is shaded, and after it is fixed in that manner at each end of the cylinder, the ring *i* may be extended from the cylinder by means of the larger screws R, and the wire thereby strained down tight upon the surface of the cylinder; this part of the mechanism is also represented in the plan, fig. 381, where the different parts are marked in the same manner, except that the woven wire is drawn in black.

Fig. 383 is a representation of a connected web of laid wire, which may be laid over the cylinder exactly in the same manner as the wove wire, observing that the laid wires should be parallel with the axis, and the tying wires *e e e* at right angles with it, observing that the laid wires must be very fine, placed very near together, and drawn as tight as possible at the ends. The reason of laying the cross wires *d d d* diagonally, is principally in order that they may not be parallel with the laid wires, in which case they would impede the passage of the water; for this reason they ought to lay at an angle as near 45 degrees as may be convenient; but if the cylinder is intended only for the manufacture of wove papers, the cross wires may be parallel with the axis, the holes ranged in rows also parallel with the axis, and the threads of the screw converted into small beads. There are other modes of constructing a cylinder possessing the necessary requisites, but the patentee thought it expedient only to describe that which he considers easiest of construction, most durable, and most efficacious in use. He also proposes connecting the rings mentioned as the fourth requisite, as being necessary for covering part of the surface of the cylinder, completed as above at the ends with arms, so as to form caps that may be fixed on to the ends of the cylinder, and each being furnished with an axis, it can then be fixed in bearings for the purpose of being turned by any convenient power.

Fig. 384 is an outline section, representing it in that situation, with a vessel fixed against it, which is called a back; the sides or cheeks of which are curved, so as to correspond with the rings or surface of the caps; and the bottom, at the point *s*, is made to close in upon the surface of the cylinder, so that the vessel on all sides fits the cylinder in such manner, that, if fixed against it, and filled with any fluid, the fluid would have no means whatever of escaping, except by running through the surface of the cylinder, and out at the ends: the exact shape of this vessel is not material. He next takes a triangular trough, or receiver, closed up at the ends, and made so that the upper edges fit the inside of the cylinder, and of such a depth that the bottom may be about level with the centre of the cylinder, so that this being fixed, and the cylinder turned round, every part of the upper edge may rub against the inside of the cylinder, which we have before said must be perfectly smooth. In fig. 380 a section is shown of this trough, which has an orifice at one end, at the bottom, marked *m*. It may be observed, that at the points *n n* it comes in contact with the internal surface of the cylinder.

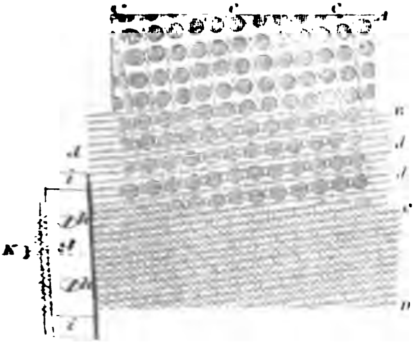
Fig. 385 is an outline vertical section, wherein the trough is represented fixed in the inside of the cylinder, and coloured blue, with the orifice *m* and pipe communicating with it *n*. It is to be observed, that this trough is firmly fixed by means of a plummer block *o o*, which has the top coupling screwed down fast, and the trough is supported at the other end by means of a cylindrical pin, which works in a hole in the cap *a*. The other cap *b*, instead of an axis, has a hole in the middle, fitted to the outside of the pipe *n*, so that it forms a bearing for that side of the cylinder. The axis of the cap *a*, at the other end of the cylinder, is supported in a bearing, and has upon it a cog-wheel *p*; by means of which motion may be communicated to the cylinder, and as it turns round it rubs against the upper edge of the trough, which will remain fixed, and receive any fluid that passes through the upper part of the surface of the cylinder, and carry it off through the orifice *m* in the same section. The cylinder is coloured yellow, the caps red, and the parts which answers to the rings are shaded.

Fig. 386 is a front view of one of the caps.

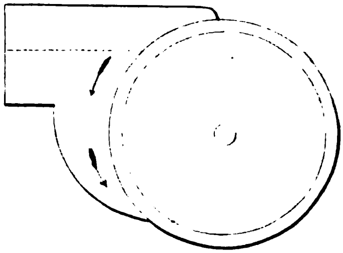
Fig. 387 is a sectional elevation of the machinery, in a state of preparation for the manufacture of paper.

Fig 388 is a plan of the same. Each part in the elevation, fig. 387, is on a line with the same part in the plan, fig. 388; and every part is marked with the same letter in both. A is a circular stuff-chest, into which the stuff is admitted from the engine. B is an agitator, consisting of a number of arms; connected with the spindle C, which passes up through a tube D, in the centre of the chest, and this being turned by the bevelled cog-weel E, keeps the stuff in motion in the chest, and also, by means of the two riggers F F, gives motion to another small agitator, in the smaller vessel G, which is for the purpose of receiving the stuff from the first chest, and it is conveyed through the pipe H, the aperture of which is enlarged or contracted by means of a conical valve, which is acted upon by some apparatus I, on the principle of a ball-cock, so that as the vessel fills with stuff it gradually closes the orifice; by this means the stuff in the smaller vessel G may be kept at a uniform height, and the head being uniformly the same, the discharge through the pipe J at the bottom will be always equal. The large chest A may be of any shape or dimensions, and agitated in any convenient manner; the smaller chest G ought to be circular, and about 18 inches diameter, and the same depth. The use of it is to cause an uniform discharge, which would not take place if the stuff were to pass from the large chest without any intermediate vessel; because its passage through the pipe would be more or less rapid, according to the height of the head, which would be continually varying in proportion to the consumption or accumulation of stuff. In the pipe J there is a cock K, by means of which the quantity of stuff that is permitted to pass may be regulated with the greatest degree of nicety; and when it is once ascertained what proportion of stuff is required, no variation in the supply can take place. The best sort of cock or valve for the purpose will be such an one as leaves an opening for the stuff, which is nearly round or square, because if it were narrow the stuff might lodge. The pipe J descends into the pipe K, through which there is a constant and rapid flow of water, and it carries away the supply of pulp from the pipe J, and they pass together into the vessel L, in which there are two agitators M M, kept in pretty quick motion by means of the riggers N N. In this vessel and in the pipe K the water and stuff become intimately mixed and formed into pulp, of a proper consistency for working; but it is to be observed, that in making paper by this method about four times as much water should be introduced into the pulp as is made use of in the ordinary modes of paper-making. From the vessel L the pulp flows through the pipes O O into the vessel P, which has been before described in fig. 384, and called a back. Q Q are waste pipes, for adjusting the height of the head, or, in other words, the level of the pulp. In the back R is the hollow cylinder, described in figs. 380, 381, 382, 383, 384, and 385, and the cylinder being in motion in the direction described in the drawing, the water is constantly flowing through the surface of it from the point S to the point T, that is to say, through every part which is covered by the pulp, and, as the water passes through, the fibres of rag are left on the surface, so that they are generally accumulating on any given part of the surface of the cylinder during the whole of its passage from the point S to the point T: and when it emerges from the pulp at the point T, the quantity requisite for the composition of a sheet of paper is collected, From 381 to 383 & 387 to 392

381 p 380



390 p 384



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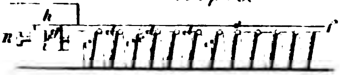

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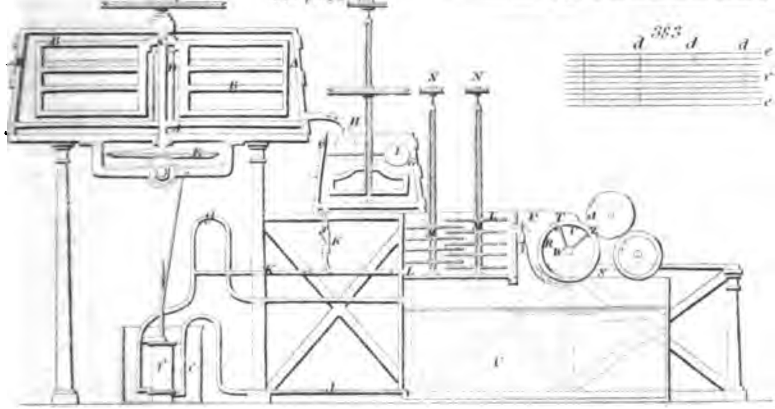
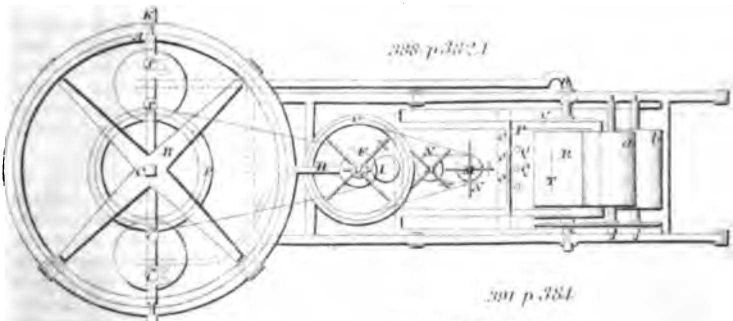
387 p 382



388 p 382 1



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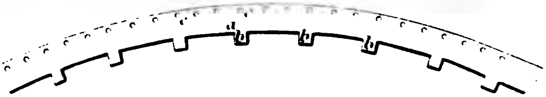
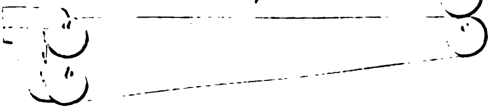


389 p 385



392 p 385

and this takes place in endless succession as long as the motion is continued, and an uniform supply of pulp is kept up. It has been before stated, that when the surface of the cylinder emerges from the pulp at the point T, the quantity of fibre requisite for the composition of a sheet of paper is collected; but at that period so much water is contained among them, that it is necessary to drain off the greater part of it before it will admit of any sort of pressure usually made use of for squeezing out the water, and for compressing the fibres of rag together, for the purpose of making them cohere, and thereby giving tenacity to the paper. For this purpose the trough V, the construction of which is more fully explained in figs. 380 and 385, is fixed in the inside of the cylinder, and made to fit tight all round its upper edge. It has a communication with the pipe W, as is represented in fig. 385, where the pipe is pointed out by the letter *n*; and this pipe is connected with a pair of double-acting pumps X X, placed in a cistern of water, so that when those pumps are put in motion, the air contained in the triangular space, enclosed between the trough and the cylinder, is immediately drawn out, and consequently the pressure of the atmosphere takes place upon the surface of the cylinder, which is covered with pulp, in the state before described, and thereby rendered nearly impervious to the air. The immediate effect produced is the squeezing out the water, and laying the pulp down in a compact state on the surface of the cylinder, so that the paper cannot be disturbed at the point Z, by the pressure of the solid roller *a*. This part of the process I call the *pneumatic* pressure. The periphery of the roller *a* moves it exactly the same rate as the periphery of the cylinder R, and in the direction described in the drawing. The roller *a* is made to fit in exactly between the inside of the caps, described in fig. 385, so that it shall only press upon the paper covering the surface of the pervious cylinder. The surface of the roller A should be smooth, and the paper will adhere to it instead of the pervious cylinder R, and be led round by it to undergo a second pressure between the roller *a* and the roller *b*, which latter has a pervious surface, consequently the paper will be produced sufficiently dry for leading off to the cutting. It is well known by paper-makers, that, independent of the quality of the materials, the strength, smoothness, and beauty of papers depend upon the arrangement of the fibres of rag of which it is composed; that in a well-made sheet of paper the fibres are ranged in a horizontal and parallel direction, and a manufacturer describing such a sheet of paper, would say that the stuff was well shut, which quality all paper must possess in a greater or less degree, because otherwise the parts of the sheet will scarcely cohere together, the surface will be rough, the thickness uneven, and the paper devoid of beauty, and not adapted for use. In the modes of paper-making exercised hitherto, this indispensable object has been accomplished by shaking the mould or wire on which the pulp is settling, so that, as the water runs off, the fibres are laid flat upon the surface of the mould, and arranged in a parallel direction; but in making paper by the machinery above described, the stuff is perfectly well shut, without any shaking, the fibres of rag being deposited gradually, in a longitudinal direction, by means of the friction which takes place upon the cylinder, in consequence of its motion being in an opposite direction to that of the stream of pulp, the effect of which is to smooth down the fibres of rag as they are upon the cylinder, and it is necessarily continued during the whole time of the formation of the paper, and must be uniform throughout every part of it. The reason of introducing so large a quantity of water into the pulp, is in order that every fibre may be afloat separately, and at liberty to take a direction according to the influence of these courses.

It is to be observed, that the principle here developed would admit of other less eligible modifications, such as confining a body of the pulp on the surface of an endless well of woven wire, carried round cylinders, as in the outline section, fig. 389, or supporting it on a cylinder of a large size, as in the outline section, fig. 390, without applying the pneumatic pressure in either case.

In fig. 389 the cylinder *a b c* should be hollow, and have pervious surfaces.

In fig 390 the cylinder might be of a more simple construction than that described in figs. 380, 381, 382, 384, and 385, but unless of a very large size indeed, it could only be made use of for making very thin papers, because the water requires so long time to run off before the paper will admit of any mechanical pressure.

It is to be observed, that in making paper by this method, after a certain quantity of fibres of rag are deposited on the surface of the cylinder, it renders the passage of the water and the accumulation of more fibres so difficult, that without a considerable height of pulp the pressure will not be sufficient to force the water through the cylinder, and the fibres of rag laying upon it, the consequence of which would be, that the fibres of rag accumulated on the surface of the cylinder would be washed off by the pulp, or very much disturbed before they arrived at the point T, which is the level of the pulp in the back; to obviate this, it will be necessary to add the pressure of the atmosphere to the weight of the water in making thick papers, which may be done by extending one side of the trough V below the level of the pulp, so as to cause a suction under that part of the cylinder which is covered by the pulp, as well as under that part which has emerged from it. For this purpose a wider trough would be necessary; but at all events the exact proportion of the cylinder, covered by the trough, is not material, because it will be found by experience what width is sufficient for drying the paper, so as to enable it to have the pressure of the roller *a*. The roller *a* ought to press on the cylinder R about the point which is over one side of the trough V, and, according as the trough is shifted, the roller should be shifted also; but this pressure ought to be not less than forty-five degrees above the level of the axis, because, otherwise, part of the water pressed out of the paper will be absorbed by it again, whereas, from the position it acts in, in the drawing, fig. 387, the water will be sucked into the trough. The roller *a* should not be fixed in bearings, but confined down upon the cylinder by weights, suspended upon each end of the axis, which may be adjusted according to circumstances, and in all cases the principal pressure should be upon the roller *b*. The water which runs through the cylinder in fig. 387 and 388, and out at the end, falls in the first instance into the cistern C, from whence it passes through the pipe *d* into the cistern *e*, and from thence is, by means of a pair of double-acting pumps *f f*, forced through the pipe K into the vessel L, so that it continually returns for the same purpose of conducting the pulp of the cylinder from the pipe J. The pipe G is a sort of gauge, by means of which, after the pulp rises to a proper height in the vessel L, the remainder of the water is carried off into the cistern C, where there may be a waste pipe for conveying off the superfluous quantity. The water drawn from the cylinder R, through the trough V, by means of the air and water pumps X X, may run to waste. The size of the cylinder R, and of the trough V, must be regulated according to the substance and dimensions of the paper it is intended for making. Fifteen inches will be sufficient for the diameter of a cylinder intended for making paper equal in substance to a paper twenty-two inches by seventeen inches and a half, weighing twenty pounds per ream; the length of the cylinder is entirely arbitrary. The thickness of the paper made by a cylinder may be adjusted in various ways: first, by using cylinders of various diameters; secondly, by accelerating or retarding the motion of the cylinder; thirdly, by varying the proportion of the surface of the cylinder, which is covered with pulp; fourthly, by varying the consistency of the pulp. The periphery of the cylinder ought to move at the rate of about thirty-six feet per minute; the pulp ought at all events to be very thin, and therefore the most eligible mode of adjusting the thickness of the paper would be by varying the proportion of the surface of the cylinder, which is covered with pulp; consequently for thicker papers a larger cylinder would be necessary, or a back may be made use of, extending higher up towards the point Z, so as to cover a larger proportion of the surface of the same cylinder: and for thinner paper a back might be made use of covering less of the cylinder, as in fig. 390, by means of the cock in pipe J. The quantity of pulp supplied to the cylinder can be adjusted with the greatest accuracy, consequently the thickness of the paper may be preserved uniform, or varied at discretion, provided the thickness of the pulp in the chest A, and the motion of the cylinder R be continued uniform. By means of the gauge pipes Q the level of the pulp in the back P can be varied till the most eligible point for the cylinder to emerge from the pulp is ascertained, and the supply of water through the pipe *r* must be adjusted accordingly. It may be laid down as a general rule, that the thicker the paper the higher should be the level of the pulp in the back. In order to close the trough V tight upon the cylinder R, the patentee proposes packing it all round the top, where it comes in contact withinside of the cylinder, as at the points *n n*, in the section fig. 380.

The mode of packing is so well known, that it is unnecessary to give any description, except the representation in the drawing. The friction of the back P upon the cylinder may be taken off by strips of woollen cloth or leather, particularly at the line across from the point S.

Figs. 391 and 392 are for the purpose of explaining a more simple mode of construction. A is a hollow cylinder, with a pervious surface, which may be used in cases when the pneumatic pressure is not applied; *a a a* is the thread of a screw; *b b b* represent cross-bars, carried across the internal surface parallel with the axis. The best mode of constructing it will be to cast a cylinder with the bars in the inside, and to cut the screw deep enough to form an opening between every bar. It should be furnished with cross wires, *c c c*, and covered with wove wire, in the same way as the cylinder R. It might be made on a larger or smaller scale, according to the purpose for which it is required. The roller *b*, in figs. 387 and 388, may be made in this manner, but stronger as a great degree of pressure is intended to take place upon it.

When the machinery is to work, the agitator and pumps should be set in motion, first by turning the shaft K, and then the cylinder R, by means of the cog-wheel P, which gives motion to the rollers *a* and *b*, by cog-wheels *q* and *r*. The mode of giving motion, and the situation of the pumps and stuff-chest, may be arranged according to convenience, but the motion ought to be perfectly regular.

COTTON MANUFACTURE.

Cotton is a fibrous vegetable substance, the produce of a small tree called the gossypium, or cotton plant, which grows naturally, and is much cultivated, in the tropical regions of Asia, Africa, and America.

The cotton, when collected from the pod, contains the seed, and pieces of the husk by which it was enveloped is attached to it; it has therefore, preparatory to being subjected to the operation of spinning, to undergo a process that will divest it of these superfluous parts. The ancient mode of effecting this was by what is termed bowing it; that is, exposing it to the action of a bow, about four feet long, such as is used at the present day by hatters. The process consisted merely in placing the cotton upon a square table with horizontal chinks cut through it, and submitting it to the repeated action of the bow until the dust, seed, and superfluous parts had separated and fallen through the chinks. This inconvenient and desultory mode has in modern times been superseded by a far more effectual and expeditious one, by the application of a machine called a *gin*. Gins are of two kinds, the one called the roller-gin; the other the saw-gin.

The *roller-gin* is represented in fig. 399. It consists of two shallow fluted rollers *a* and *b*, placed so near to each other, that when the cotton is thrust against the line where they enter into contact, they immediately seize hold of it and draw it in between them, while the seeds and other particles, not being able to pass through, fall into the box K, and are, by the slanting direction of its bottom, delivered on one side. The motion is communicated by means of the treadle and crank C D, and is equalized by the fly-wheel E. The cotton is presented to the rollers over the board *f g*, and is drawn between them, and delivered at I H. In South America this kind of gin is much used, and a negro working with one of them can clean from 30 lbs. to 40 lbs. weight of cotton per day, which, however, is considered heavy work.

The *saw-gin* is given in section in fig. 400. The cotton is thrown into the receptacle A B, on that side marked C D, which is formed of strong wires placed parallel to each other, to admit the circular saws E, fixed on the axis F, behind the grating, about an eight of an inch apart, to pass between them. By this means, the teeth of the saws seize hold of the cotton and draw it through the bars; and the seeds and other superfluous parts, being two bulky to pass through, remain behind, and eventually fall through the aperture G. The cotton is brushed from the saws by a circular brush H, made to revolve rapidly on its axis. The motion is communicated by manual or any other power applied to the axis F, upon one end of which is the wheel K, acting in the pinion M, fixed to one end of the axis of the brush.

The application of the power of horses to either the roller, or saw-gin, would greatly aid the process, which, as we before have stated, is considered heavy work for the negroes, and on that account is much avoided. An objection has been started to the applying of this power, under a supposition, that the animal by changing his speed would injure the cotton; it is almost superfluous to add that many simple contrivances may be adapted to equalize the motion, and prevent these dreaded effects.

When the cotton has undergone either of these processes, it is packed, and exported to the European markets.

When it arrives in this country, it is again submitted to the action of machinery for the further separation of the extraneous matter, unless it is to be spun into coarse yarn, when the preceding process is considered sufficient.

The first machine that we shall describe as used in this country for the further clearing of the particles is called a *picker*, and is represented in fig. 393. A and B are two rollers, having an endless-cloth, C D, stretched over them. This cloth is called the feeding-cloth, and its upper surface is, by the revolution of the rollers, always carried towards D. E and F are two fluted rollers, which nearly touch each other, and revolve, so that their touching surfaces pass towards G H. G H I K are cylinders, covered on their outer surfaces with long blunt pins, making about 250 revolutions, in the direction of the letters, per minute. L L is a grating of wires for the seeds to fall through, when the cotton carried by the feeding-cloth is delivered by the small rollers upon the face of G H. By the rapid revolution of G H, the cotton is thrown against the top O P, and is carried forward and delivered upon the cylinder I K, which in like manner carries it rapidly round, draws it over the grating, and delivers it back upon the lower face of G H, which after having drawn it over the remainder of the grating, and divested it of the remainder of the seeds and particles of dust, deposits it in the box R R.

This machine is liable to injure the staple of the cotton, and is therefore superseded by another called a *batter*, represented in fig. 401. In this machine, the feeding-cloth upon the rollers A and B carries forward the cotton to the rollers *c* and *d*, which deliver it upon the curved rack or grating *d e*, while a scotcher, *g h*, revolving rapidly upon its axis, strikes the cotton with its two edges *g* and *h*, and divides it; at the same time a draught of air, created by the revolution of the fan I, blows the cotton forward over the grating K K, divests it of the superfluous parts, and ultimately deposits it in a box at the end.

The cotton is now considered in a state fit for the operation of spinning; which is differently performed according to the purposes to which the yarn is to be applied. The different sorts of spinning may be classed under the respective heads of Jenny, mule, and water spinning.

Mule-spinning, which is by far the most perfect process, and by which the finest yarn is produced, shall first have our attention.

In this process, when the finest yarn is to be produced, the cotton, instead of being submitted to the operation of either of the machines before described, is cleansed entirely by the hand. The mode of effecting this is, by spreading the cotton upon a strong netting of cords stretched on a frame, and beating it with osier wands till divested of its impurities. It then undergoes the elementary operations of carding, drawing, stretching and plying, and twisting; the whole of which are essential in the manufacture of mule yarn.

Carding is performed by two kinds of engines, one of which, called the breaker, operates upon the cotton preparatory to its being submitted to the operation of the other, called the finisher.

A card is a kind of brush, formed by making wires into the form of staples, as represented in fig. 394. The two legs of the staples are placed through holes in a flexible piece of leather, and present to the side view a form similar to that shown in the figure, where A B is the leather, and C D the wires forced through it. Cards are formed in two ways; the one called sheet-card, is made about four inches wide, and 18 inches long, or of a length corresponding with the width of the main cylinder, which they have to cover; the other, called fillet-card, is made in one continuous band or fillet, and is used for covering the doffer cylinder. The teeth of the fillet-card are placed pointing in the direction of the length of the fillet, and completely cover the cylinder to which they are applied; whereas in sheet-cards a space is left between every sheet, as may be seen on the main cylinder, fig. 395.

Fig. 395 represents a sectional view of the immediate working parts of a breaker carding-engine. A is the main cylinder, covered with sheet-cards; B the doffer cylinder, covered with fillet-card; C C C are the tops; *e g* is the feeding-cloth supplied with cotton, which has been previously weighed, moving forward over the roller, *f*, by means of the roller *g*, and delivering the cotton between the feeding-rollers H H, which carry it to the main cylinder. The main cylinder revolves rapidly in the direction of the dart, and carries the cotton upward between itself and the tops, which are covered with sheet-cards, about 1¾ inches to 2 inches wide, so that they may, as nearly as possible, follow the curve of the main cylinder. I is the lapping-cylinder, having a wooden roller I^1, laying upon its upper surface; and K is the doffer or taker-off, having affixed to it the steel comb called the doffing-plate.

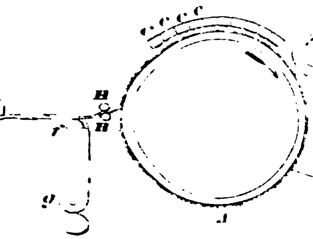
The doffing-plate may be seen more at large in fig. 396, which represents a front view of the doffer-cylinder on a larger scale. On inspecting this figure, it will be seen, that the doffing-plate L L, whose lower edge is formed like a comb, is fastened across the whole of the doffer cylinder, and is supported by the two uprights *m m*, fastened on two cranks on the shaft n^3 n^3. The upper parts of these uprights, *m m*, are fastened to corresponding cranks at *n n*, so that the doffing-plate, by the revolution of the shaft, is made to move downwards while in contact with the doffer cylinder, and upwards while away from it. The cotton is taken in by the feeding-rollers, and is carried up by the main cylinder and passed between it and the tops or flats, whose teeth lie in an opposite direction to those of the main cylinder, and by whose united action the cotton is combed, divided, and cleansed, and its fibres placed in a direction more parallel to each other.

The main cylinder, by its revolving motion, is soon covered with cotton, and is divested of it by the doffer cylinder, which is placed so as nearly to touch it, and which moves at a much slower speed, in the direction of the dart. The effect of this engine would therefore be to distribute the cotton equally over

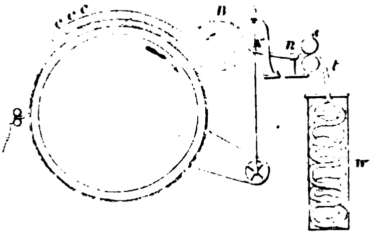
COTTON MANUFACTURE

From 393 to 398

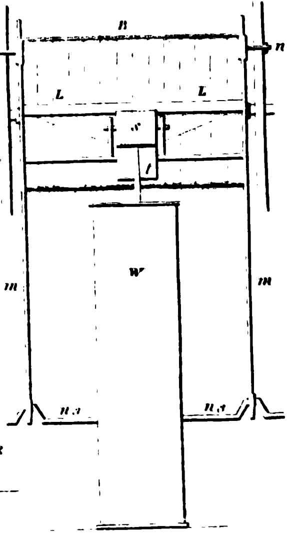
395 p 388



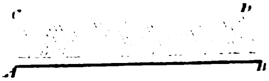
397 p 389



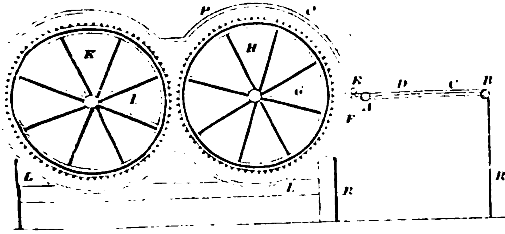
396 p 388



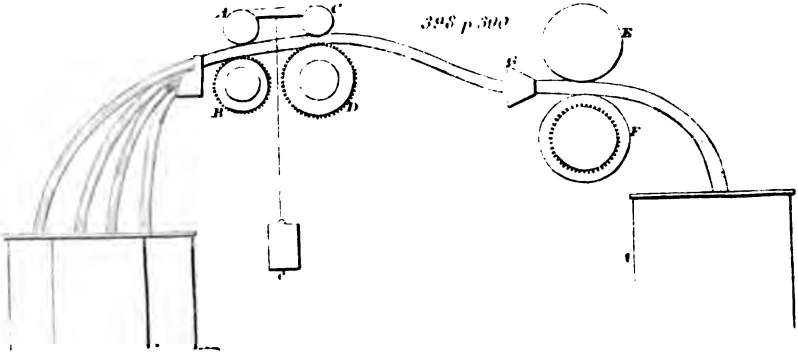
394 p 388



393 p 387



398 p 390



the main cylinder, the top cards, and the doffer cylinder; but the doffing-plate, by the action already described, is continually clearing the doffer cylinder; whose points are consequently left bare to receive a fresh supply from the main cylinder. The doffing-plate continually strips the doffer-cylinder of the carded cotton, which it delivers upon the lapping cylinder in one continuous web of about 18 inches wide, which is the usual width of the engines for fine work.

When the top cards are covered with cotton, an attendant is appointed to take them off and to divest them of the cotton by means of a card nailed on a board, which he carries in his hand for that purpose.

The quantity of work delivered to the engine is ruled by the speed of the cylinders and quality of the cotton. When it has passed through the engine, and is wound upon the lapping cylinder, (which is so adjusted as to contain about 20 laps,) the attendant lifts up the roller I^1, makes a division in the circular web, and takes it off the roller.

In this operation we are presented with the first act of plying or doubling, which is introduced in the process of spinning in order to obtain equality in the strength and thickness of the yarn.

The cotton is in this state called a lap, and is immediately taken to a finisher-engine, which, in general, is disposed back to front, immediately after the breaker-engine, as may be seen in fig. 397. The construction of the finisher-engine is exactly similar to that of the breaker-engine, except that instead of having a lapping cylinder, the cotton, when it leaves the doffer, is drawn through a mouth-piece, R, formed like the end of a trumpet, by means of the rollers *s* and *t*, and is delivered into the can W. The rollers *s* and *t* may be seen in section in this figure, and in a front view in fig. 396. Previously, however, to leaving this process, we shall make a few remarks, as it is, with much propriety, considered the very foundation of all good spinning.

The breaker-engine for spinning fine cotton is generally covered with cards of a fineness that will admit 225 teeth, or 450 points, in a square inch; and the finisher 275, or 550. But spinners are much divided on this subject, and in some mills the same work is performed with cards one-fifth coarser than it is in others. The top cards are in general one-tenth coarser, and those of the doffer cylinder one-tenth finer, than those on the main cylinder: and in some manufactories, at the back part of the engines, where the cotton first arrives, coarser top cards have been introduced, with a view of divesting the cotton of the largest particles of extraneous matter, and in some instances have been again laid aside as superfluous. Cards must be set easy in the leather, which should be thin and strong. The card-engine is driven by a strap passing from a drum over a fast and loose pulley, fixed on the shaft of the main cylinder. The fast and loose pully is represented in fig. 65 ; and its utility has been explained in the article MILL-GEERING.

To return to the manufacture, the cotton which is now in the can from the card engines, in the form of a sliver, is next submitted to the process of drawing represented in fig. 398. In this process three or four card-ends are brought in tin cans, and passed between the rollers A B and C D, which revolve with different velocities; that is, the rollers C and D revolve much quicker than A and B, and the top rollers A and C are made to press upon B and D by means of the weight *e*. Now, supposing four slivers be placed together, and passed through the rollers A B and C D, and that C D revolve so much quicker than A B, that the sliver will become four times its original length, the cotton will, by such elongation, be reduced in thickness three-fourths, that is, to the same thickness of a single sliver when first brought to the rollers. By this process the fibres of the cotton are laid more parallel to each other, in the direction of the length of the sliver, and the operation is repeated, by plying the slivers which have passed the rollers, and passing them through a similar set. The sliver when thus plied and reduced, is drawn through the mouth-piece G, by the rollers E and F, and delivered into another can.

After the cotton has been plied and drawn as many times as the spinner, from the quality of the cotton, and the intended quality of the yarn, considers necessary, it is carried to the roving-frame.

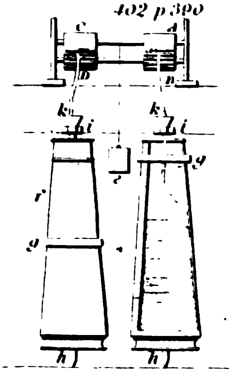
The *roving-frame*, which is much used in mills where mule-spinning is carried on, is represented in fig. 402, and is termed the *can roving-frame*. A B, two rollers, moving at a slower speed than C D; A and C are pressed upon the rollers B and D by the weight E, as may be seen in a front view, fig. 402, and section, fig. 403. The cans, (fig. 402,) are represented, the one shut, and the other open; the latter opens by means of hinges, after raising the ring *g*. The cans are capable of revolving upon their spindles *h h*, and are supported in an upright position by the collars *i i*, and have at their upper extremities funnel-shaped pieces, *k k*.

If two slivers of cotton are brought from the drawing-frame, and passed between the rollers A B and C D, the processes of plying and drawing will again take place; and the rollers C D will feed the end thus formed into the can through the mouth-piece at *k*, which, by revolving rapidly upon its axis, will impart to the end, or sliver, a slight degree of twist. When the can is filled the rollers are thrown out of geer, and the motion ceases; the can is then opened, and the cotton, or as it is now called, the roving, is taken out and wound upon a bobbin, and in that state is carried to a machine called a stretcher.

Some objections exist against this species of roving ; first, from the necessity of taking the roving out of the can for the purpose of winding it upon a bobbin, during which it is liable to sustain much damage from the fibres being in a very slight state of adhesion ; and secondly, from the roving receiving its twist solely from the revolution of the can in which it rests, and by which the twist is not equally diffused over the whole length of the roving. The first objection was attempted to

From 399 to 407

402 p 390



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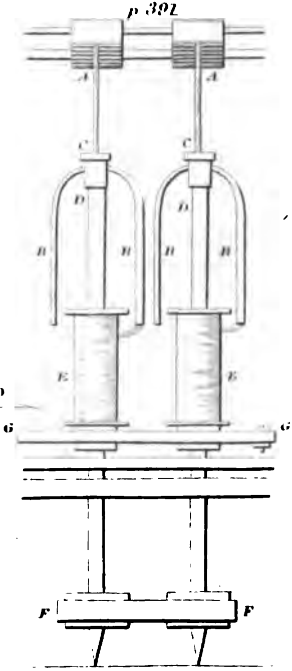

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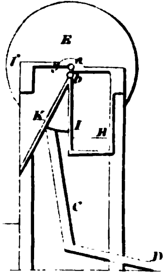

406 p 395

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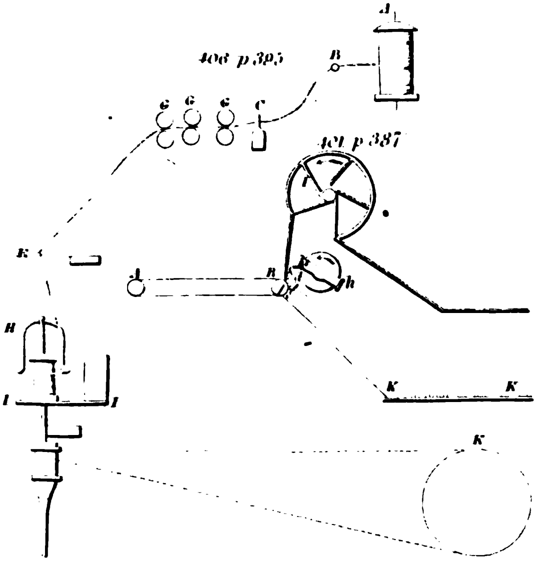
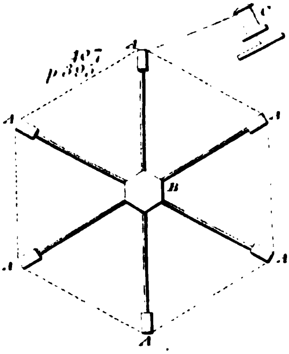


407 p 395



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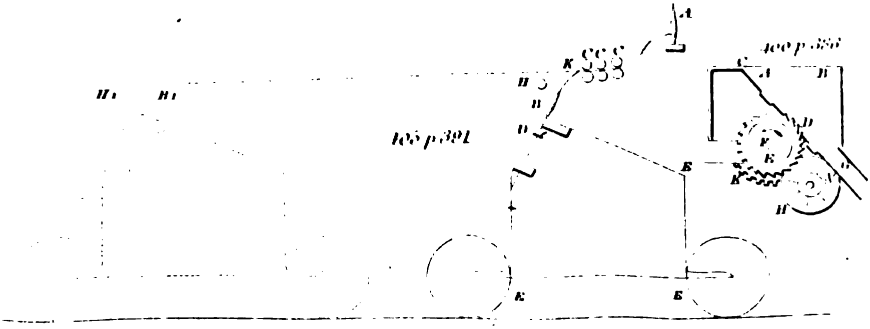
400 p 386



be obviated, by placing the can in a frame, and drawing the roving out through the mouth-piece at which it entered; and a remedy for the second was somewhat unsuccessfully attempted by Mr Arkwright, who tried to introduce a pair of rollers upon the top of the roving-can, to seize hold and feed the roving into the can as fast as it was received from the drawing-rollers. This, undoubtedly, would have perfectly equalized the twist throughout; but the machinery necessary to produce the double rotatory motion was found to be inconvenient, and the plan was in consequence abandoned.

A roving frame of a different construction, which obviates the preceding objections, and which, in consequence, has received more general adoption, is represented in fig. 404; it is called the *bobbin and flier roving-frame.* The rollers for stretching are similar to those before described; and the plied and drawn roving is represented as coming from the rollers at A, whence it passes through an eye at C, over the top of the spindle D, and down one of the legs of the flier B B, which is for that purpose formed tubular. By the revolution of the spindle D, generated by a strap acting upon the pulley F, the fliers are carried swiftly round, and twist and deliver the thread upon the bobbin E, which is moved upwards upon the spindle by raising the board G G, upon which it rests, descending again as the board descends.

The roving is, by this means, slightly twisted and wound upon a bobbin, in a fit state to be immediately carried to the stretching-frame, which, being very similar in its construction to the mule, we consider it necessary only to give a side view of one of the spindles of a mule, shown in fig. 405. A is the place where the bobbin from the roving-frame, (not shown in this figure,) would have been situate; and *c c c* are three pairs of rollers, revolving at different speeds, for the further drawing of the roving. The roving, when it has been thus drawn, is brought to the spindle B, which is formed of polished steel, ground slightly tapering to the end, which is a round blunt point. The spindle receives its motion at the pulley D, by means of a band passing round a drum in the box E E E; which drum has bands passing in the same manner to several other spindles. When the motion commences, the carriage E E E passes backwards to the position shown by the dotted lines, and carries with it the spindles to the position B1; during which the spindle revolves rapidly on its axis, and gives a certain degree of twist to the roving, which already has undergone a reduction in diameter by passing through the rollers C C C. The extent to which the frame recedes is about three yards, and when the spindles have given the requisite degree of twist to the yarn, it returns to its former place; while the attendant, by moving the bar H upon its axis, presses the yarn downwards, by means of a piece of wire K, which causes it to be wound upon the spindles, so as to form a figure that may he represented by two cones, one having a more acute angle than the other, placed base to base, as shown at A, B, and B1. This form is termed a *cop*, and the act of so distributing the yarn, by the movement of H K, the *building of the cop*.

It may here be observed, that although this is called the stretching-frame, the yarn is not stretched, but merely undergoes a further process of drawing and spinning, and that the stretching is not performed till in the next operation, which is performed upon the mule, and termed spinning.

The yarn, delivered from the stretching-frame in the form of a cop, is taken to the mule, which is, though much lighter, both in the form and action of the parts, very similar to the stretching-frame. The spindles also are of a smaller size, and are situated nearer to each other.

The *mule spinning-frame* differs from that of the stretching-frame insomuch as the act of stretching is added to the other operations; for when the frame E E E has receded a certain distance, generally about one yard, the rollers C C C cease to move, and the frame still continuing to recede, stretches the yarn. During this process, the spindles on the frame E E E move considerably quicker, in order to save time. The stretching is performed with a view to elongate and reduce those places in the yarn which have a greater diameter, and are less twisted than the other parts, so that the size and twist of the yarn may be more uniform throughout. When the cops are full, they are taken from the moving spindles, and placed on stationary parts of other mules, as at A, and the yarn is again submitted to the same process, until it is reduced and spun to the proper fineness, both as respects the diameter and the twist; during the whole of which process the yarn can be continually joined, so that the cops, which are in separate pieces, can be added to each other in parts, or otherwise, as the continual elongation of the yarn in the course of the different operations of each mule may require. The pieces are joined by children, called *piecers*, who are in attendance on each mule, to join any yarn that may be broken in the act of stretching or twisting.

The drums, which drive the spindles in those parts of the mule that recede, receive their motions from bands communicating with the moving power; but the advancement and recession of the carriage, for the purposes of receiving and stretching the yarn, as before described, is performed by means of a wheel moved by hand-labour. A spinner is enabled by experience to judge of and regulate both these operations, as also the building of the cop, which is a matter of very great nicety; for if the cop is not well built, the yarn will not run off even when it is to be used. The number of spindles on a mule amount frequently to 300. The yarn produced by mule-spinning, being by far the most perfect, is employed in the fabrication of the finest articles, such as lace and hosiery; and when it is twisted in two, four, or six plies, is used for sewing-thread.

Jenny-spinning is of earlier date, and a much less perfect process than mule-spinning; consequently it is but little used, except in the manufacture of yarn for coarse goods. In this spinning, the cotton, after having been cleansed by some of the processes already described, is, preparatory to being exposed to the action of the jenny, immersed in a solution of soap and water, to divest it of the glutinous matter generally found on the surface of this and other vegetable fibres; it is then, after the soap and water has been pressed from it, put into a warm stove, and when dry, is considered to be in a fit state to be exposed to the operation of the carding-engine.

The carding-engine used in jenny-spinning is different in its construction to the one before described; for in mule and water spinning there is a breaker and a finisher-engine; but the engine used in this process is called the double-engine; the first part, or breaker, is in the same frame with the second part, or finisher, and the doffer from the first part delivers the cotton upon the main cylinder of the second part, which, in like manner, delivers it upon the second doffer. The second doffer, instead of being covered with fillet-cards, as the doffer of the single engines, is covered with sheet-cards, like the main cylinder, but being of smaller dimensions, has generally only twleve cards upon it; therefore the web of cotton combed from such doffer by the doffing-plate is not in one continuous piece, but in several pieces or portions, equal to the quantity attached to each sheet-card upon the doffing-cylinder.

As the several small portions are delivered by the comb, they fall into the concave part of a smooth arc that is equal to one-third of a circle. In this arc a cylinder of smooth mahogany slowly revolves in such direction that the lower surface in the arc passes from the engine. This cylinder has small cavities or flutes on its surface, in a parallel direction to its axis; the angles on the projections between the flutes are taken off, so that the several portions of web which fall from the doffer into the arc are seized by the flutes, and carried forward on the concave face of the arc, and formed into a sliver, about half an inch in diameter, and of a length corresponding with the breadth of the carding-engines, which is about from 24 to 34 inches. The portions thus rolled are called rows, rolls, or rowans.

In this state, the cotton may be considered in the same relative state of progress as a card-end in mule or water spinning; but it is evident that this mode of spinning is very deficient for the purposes of fine yarn, insomuch as in the rowans the fibres of the cotton are laid across the longitudinal direction in which they are to be spun, so that the advantage derived in the other process of carding, from the fibres being placed in a direction parallel to the intended length of the yarn, is entirely lost. In this process, also, the advantage of plying, which we have noticed as taking place on the lapping cylinder, is omitted.

When the rowans are perfected by the mahogany cylinder, they are taken up by children, and placed upon the feeding cloth of a machine called the *billy*, or *roving billy*, the operation of which is called roving or slubbing; but the latter expression is now but seldom used, except in the manufacture of woollen. This machine is in its construction and action very similar to the mule, as is the feeding-cloth to that described in the machine called the picker and batter.

The feeding-cloth lays in a slanting position, and the rowans are placed upon it so that they can pass lengthwise in the direction of its action, and be delivered over the upper roller between two pieces of board which possess a capability of clasping and again relieving them. The rowans are then attached to revolving spindles, which have an advancing and receding motion similar to the mule or drawing-frame. By this revolution and recession the spindles perform the operation of spinning and stretching; and at such intervals as the spindles are stretching and twisting, the feeding-cloth stops, and the clasps seize hold of the roving, and detain it till sufficiently spun and twisted, when it relieves it in order to allow a further portion of the rowan to be fed. The roving having by this means received a certain degree of twist, is built on a spindle in the form of a cop, as in mule-spinning, and is then taken to the machine called the jenny.

The operation of the *jenny* is nearly the same as the roving-billy; the only material difference is, that the cops of roving to be spun are fixed upon a moving carriage, which has clasps to hold the roving while in the act of being stretched and spun into yarn.

Having now concluded the process of jenny-spinning, it will be seen, that drawing and plying, the two essential requisites for producing fine yarn, by placing the fibres parallel to the length of the twist, are wanting, and that fine yarn, in consequence, cannot be produced; but the fibres in this process being placed in a direction more across the length of the twist, give to the yarn a rich fulness which renders it preferable for the weft of heavy goods, for which it is esteemed.

Water-spinning differs both from the mule and jenny-spinning; but the carding and drawing machines are the same as those used in the process of mule-spinning. When the cotton has passed through the carding and drawing machines, it is carried to the spinning-frame, which is upon a different principle to the mule, and, indeed, is more closely allied to the bobbin and flier roving-frame.

One of these spindles is represented in fig. 406. A, the bobbin, brought from the roving-frame; B C and E guides for the yarn to pass through; G G G three pairs of rollers to perform the office of drawing; and H a flier, formed solid, and having at the end of one arm a small twist like a corkscrew, through which the yarn passes. By the revolution of the flier the yarn receives the requisite degree of twist, and is wound upon the bobbin, which, by the movement of the seat I I, on which it rests, has an upward and downward motion, in order that the yarn may be received upon it regularly. The guide C has a slow reciprocating motion in the direction of the axes of the rollers G G G, by which the roving is moved over the surfaces of the rollers, so that the parts wear uniformly.

In water twist-spinning, the operation of stretching is not introduced. The motion is transmitted from the first mover to the drawing and roving frames by means of bevel-wheels, placed on the end of the frame. These wheels communicate motion to the rollers, which have spur-wheels upon their shafts, adapted to give motion to each other by intermediate wheels, which give to the lower rollers motion in the proper direction. The spindles receive their motion from bands communicating with the drum K, represented by the dotted lines. This construction of a water spinning-frame is called a *throstle*, and the difference which characterises it from that properly called the water-frame is, that the cylinder K runs through the whole length of the frame, and gives motion to all the spindles at once; whereas in the water-frame the spindles are moved by an upright pulley, communicating motion to only one set of six spindles, which is an advantage, as the motion of one set can be stopped without stopping the motion of the whole. But as the water-frame is far more expensive than the other, it is a matter of doubt which ought to be preferred.

The several sorts of yarn have each their peculiar destination. The yarn from mule and jenny spinning is taken from the frame in the form of a cop; that from water-twist is wound upon a bobbin. The yarn from water-frames possesses much regularity and strength, and is mostly used for the warps of heavy goods, such as fustians and strong calicoes. If the yarn has to be packed for the market, it is reeled upon a frame consisting of six horizontal bars supported on an axis parallel to each other.

This frame is represented in section, in fig. 407. A A A A A A the horizontal bars; B the axis; and C the bobbin from the water-frame. The dotted lines represent the direction of the twist. These reels are of a sufficient breadth to wind off about 50 cops, or bobbins, at the same time.

When the reel has made 80 revolutions, a small bell that is connected with the machinery rings, and warns the attendant to stop the motion of the reel. The portion thus wound is called a lay, and seven of these lays wound upon the same reel constitute a hank, which is taken from the reel by causing one of the horizontal bars, supplied with a hinge, to fall inwards. The circumference of the reel is a yard and a half; consequently the hank measures 840 yards. The size of the twist is expressed by stating how many hanks go to the pound weight: thus, the yarn called N° 100 is that which takes 100 hanks of 840 yards each to weigh an avoirdupois pound. Yarn can be spun upon mules as fine as 200 hanks to the pound; but in water-twist and jenny-spinning it seldom exceeds 60 or 70.

The plan of the buildings in which the cotton-spinning machinery is placed, is generally in the form of a parallelogram, of a length proportionate to the extent of the manufacture carried on therein, and about thirty feet wide. In the best constructed mills, the carding and other preparatory machines are placed on the lowest floor; the mules and stretching frames on the next; and so on progressively as the machines improve the fineness of the yarn. The mules, jennies, and water-frames are placed with their line of spindles across the building; and the card-engines have the axes of their cylinders parallel to the long wall of the building. Four or six rows, breakers and finishers, are placed alternately.

The steam-engine, or first mover, is placed at one end of the building, and the motion is communicated by a horizontal shaft running the whole length of the building, which transmits the motion to vertical shafts with bevel-wheels, which wheels transmit the motion to horizontal shafts in the upper floors.

WOOL MANUFACTURE.

This well-known staple is in the process of the manufacture divided into two distinct classes, *long wool* or *worsted spinning;* and *short wool,* or the *spinning of woollen yarn.*

ON WORSTED SPINNING.

Having by means of machinery accomplished the formation of a thread of cotton, the application of the principle to other fibres would naturally follow; and although some difficulty might be expected to occur in adapting the rollers to different staples, yet this was soon overcome. The methods of forming threads from long wool and from flax, by the hand, were very different, yet each was spun from the middle, not from the end, of the respective fibre. In hand-spinning, the pluck, that is, the portion plucked from the sliver or combed wool, was placed across the fingers of the left hand and from the thick part of it, the fibres were drawn, and twisted, as the hand was withdrawn from the end of the spindle, to which it had been previously attached. The revolution of the wheel, effected by the right hand, conveyed by a band to the whirl, or pulley on the spindle, produced the requisite twist to give firmness to the thread; and by a very gentle motion of the same wheel, the thread being brought nearly perpendicular to the spindle, it was wound upon the spindle to form the cop. From this it was transferred to the reel, and became a hank, of a definite length, but varying in weight with the thickness of the thread. In this state it was transferred to the manufacturer to be converted into the different fabrics of shalloon, calimanco, bombasin, &c.

A few years after the introduction of cotton machinery, an obscure individual of the name of Hargraves, previously unknown as a mechanic, who had been long employed by Messrs William Birkbeck and Co. at Settle, in Yorkshire, in the management of a branch of the worsted manufactory, attempted to spin long wool by means of rollers. He constructed working models of the necessary preparing machinery, and of a spinning-frame, by the assistance of persons accustomed to the construction of cotton machinery, and succeeded so completely, as soon to induce his employers to build a large mill for its application. By degrees his plans became known to the trade, and many large manufactories have subsequently been erected for this purpose. Contrary to the earlier anticipations on this subject, it has been found, that mill-spun yarn answers better for the coarse as well as the finer fabrics, than that produced by the hand, which it has entirely superseded.

The first process after the wool of the fleece has been properly sorted, as it is termed, and washed, is combing. This is either done by the hand or by machinery, invented for that purpose some years since by the ingenious Dr Cartwright. The object of each mode is to arrange the fibres as much as possible parallel to each other, which, as they have a somewhat tortuous form, and are of considerable length, requires them to be frequently drawn from each other by the exertion of the strength of the wool-comber or the machine. In this state they form a bundle of fibres about six feet in length, called a sliver, and this being laid upon the stretching or drawing frame, constitutes the commencement of the preparing process. The wool passes through several pairs of rollers, of which the first and last are of course the essential ones, the intermediate moving with equal velocities, and consequently serving merely to conduct the skein : this is received in cylindrical cans; and three such skeins being passed through another drawing-frame, and stretched in their progress, become fitted for roving, the last step in the preparatory processes. Allowing for the difference in distance, of rollers and weights, which on account of the length and adhesiveness of the fibres of wool, are both necessarily greater than with cotton, the description of the bobbin roving machine already introduced, will be sufficiently explanatory.

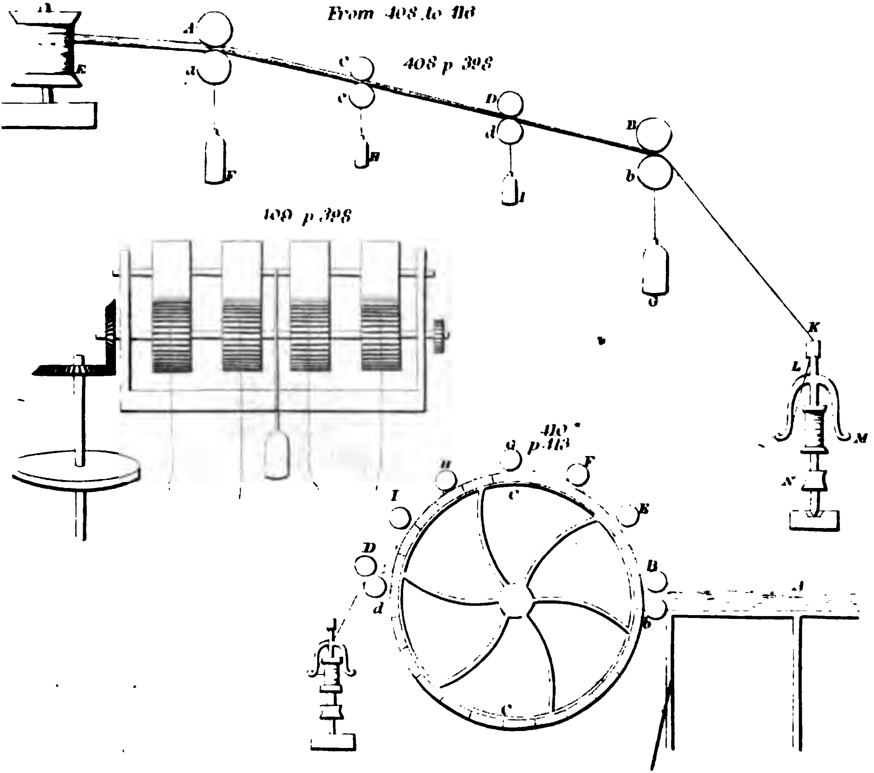
Spinning, the concluding process, is effected by means of two pairs of rollers moving with unequal velocities, and intermediate auxiliaries.

The loosely twisted thread from the roving bobbin, E, fig. 408, is slowly carried forwards by the holding rollers A, *a*, and supported as it proceeds by the two pairs, C, *c*, and D, *d*. It is then drawn between the rollers B, *b*, and having been thus brought to a proper thickness, is twisted by the flier, L, fixed on the top of the spindle, through which at K it passes: it is then taken up by the bobbin M, which moves round with the spindle its axis, although not equally quick. The ultimate thickness or size of the thread is determined by the difference of velocity in the holding and drawing pairs of rollers; that is of A, *a*, and B, *b*, which in their operation evidently imitate a pair of hands. The celerity of the three pairs of rollers nearest to the back of the frame is equal; consequently no stretching takes place amongst them. The upper rollers of the first and last pair are pressed down upon the lower, by weights, F, G, much heavier than H, I, which are supported by the axes of C, D; these being only required steadily to carry forward the skein, and prevent the remote ends of the fibres of the wool from starting, whilst B, *b*, are pulling their other extremities. The front rollers belonging to one division, or box, as it is commonly termed, are represented in fig. 409, where the drum, which moves the spindles, and by a bevelled pinion at the top of its axis conveys motion to the rollers, is also shown. The pinion on the right extremity of the roller, acting upon a train of wheels properly adjusted, imparts the required relative motion, in succession, to the rollers beyond.

SHORT WOOL.

Short wool is wrought into the finest cloths for personal wear, and is spun in a manner similar to cotton, as described in jenny-spinning.

From 408 to 416



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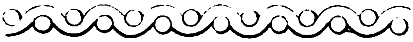
412 p 419



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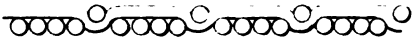

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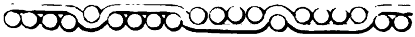
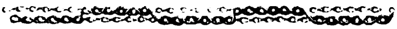


415 p 420



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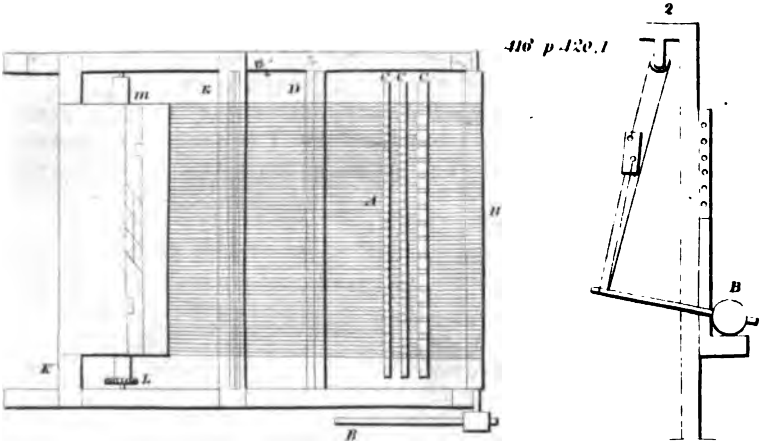


The first stage of the manufacture consists in submitting it to the action of chamber-ley and frequent rinsings in clean water, which bring it to the state fit for the operation of carding. The carding-engine for fine short wool is constructed with one main cylinder, having, in lieu of the top cards used in jenny-spinning, numerous small rollers, lying and rolling upon its upper surface; it is used in place of a breaker-engine, and it called a *scribbler*. The wool is delivered from a main cylinder to a doffer, and, being combed or doffed, is carried to another engine, called the *carder*, which perfects the carding, and delivers it off, by means of grooved mahogany rollers, in a row or rowan, as in jenny-spinning. If the wool is of a coarse description, such as is formed into yarn for the manufacture of coarse cloths or wollen cords, more carding is required.

The *scribbler-engine* has three distinct parts or cylinders in one frame. The first part consists of the first main cylinder with its top rollers, and is called the breast; this delivers the wool to the second main cylinder, which, with its top rollers, is called the first part; this delivers it to a small intervening cylinder, called the 'tween doffer, which carries it to the third main cylinder, which, with its top rollers, is called the second part; from hence it goes to the last doffer cylinder, from which it is combed by a doffing-plate, and finally carried by hand to a carding-engine.

The *carding-engine* consists of similar parts to the scribbler-engine, except that it has no breast cylinder, and is covered with finer cards: its last doffer delivers the wool to a mahogany grooved roller, which forms it into rowans for the process of spinning.

The act of continous carding, as described in mule-spinning in the cotton manufacture, is said to have been effected in some mills, but the advantages arising from it are not so great as to procure it general introduction.

The rows or rowans are taken to a roving-billy, which we have already noticed in jenny-spinning, and is spun and stretched by hand as there described. In this, however, the act of plying and drawing is not introduced, as fineness of yarn is not the object sought.

The engines used in carding wool are generally larger than those used for cotton, being frequently six feet wide; during the operation of carding, the wool is copiously sprinkled with rape oil.

SILK MANUFACTURE.

Silk is a very fine and delicate thread, the produce of a small insect, called *bombyx*, or the silk-worm; which is not less curious on account of the changes it undergoes in its existence, than valuable for the beautiful fibre which it spins. The egg, requiring not the care of parental incubation, is by the solar heat brought into existence, and the bombyx or silk-worm thus produced lives upon the leaves of the mulberry-tree until it has arrived at maturity, when, spinning itself up in a small bag, about the size of a pigeon's egg, it is changed into an aurelia. In this state it continues till about the fifteenth day, when it is changed into a butterfly, and, if not prevented, eats its way through the silken prison, to expand its newly acquired wings in the sun.

The ball or cocoon, which the ingenious little insect has been at so much pains to spin, to secure itself from its enemies and the effects of the weather, is the substance we call silk; and many who have examined it with attention are of opinion that it will extend to the distance of six English miles.

In order to secure the silk for the purposes of the manufacturer, it becomes necessary to destroy the insect so soon as the cocoon is completed, which is on or about the tenth day. The cocoon is of various colours; but the most predominant are flesh colour, orange, and yellow. The whole of them, however, are lost in the process of scouring and dying, and therefore it is not necessary to wind them on separate reels.

The balls, preparatory to being wound off into skeins or hanks, are immersed in hot water, which dissolves a natural gum, by which the fibres are united together, so that a single thread taken from the reel will be found to be composed of numerous small fibres or threads in the state produced by the worm.

The silk is imported into this country thus wound off into skeins, and in order to undergo the processes of the manufacturer is wound upon bobbins; and each thread being, as we before have stated, composed of several fibres, receives a certain degree of twist, that the constituent parts may be united more firmly together than they can possibly be by the gum alone. When they have been subjected to thus much of the manufacture, they are wound upon fresh bobbins, and two or three threads twisted together, to form a strong thread for the weaver, who warps and finally weaves the silk into various beautiful and useful articles, by a process very similar to that used in the weaving of cotton and linen.

In Piedmont, where very excellent silk is produced, the manufacture is carried on by aid of the silk reel represented in fig. 424.

The balls or cocoons are thrown into hot water contained in a copper basin or boiler, A, about 18 inches in length, and six deep, set in brick-work, so as to admit of a small charcoal fire beneath it. B B is a wood frame sustaining several parts of the reel; D is the reel upon which the silk is wound; C is a guide which directs the thread upon it; and E F the wheel-work which gives motion to the guide. The reel D is merely a wooden spindle, having four arms mortised into it to support the four battens or rails on which the silk is wound.

Upon the end of the wooden spindle of the reel, and within the frame B, is a wheel of 22 teeth, which gives motion to another wheel C, fixed upon the end of the inclined axis E F, and having twice the number of teeth; at the end of this inclined axis is another wheel G, of 22 teeth, playing in a horizontal cog-wheel with 35 teeth. This wheel turns upon a pivot fixed in the frame, and has a pin fixed in it at a distance from the centre, to form an eccentric pin or crank, and give a backward and forward motion to the slight wooden rail or layer C, which guides the threads upon the reel; for this purpose the threads are passed through wire loops or eyes, C, fixed into the layer, and the end thereof opposite the wheel and crank F is supported in a mortise or an opening made in the frame B, so that the revolution of the crank will cause the layer to move, and carry the threads alternately towards the right or left. There is likewise an iron bar H, fixed over the boiler at H, and pierced with two holes, through which the threads pass to guide them.

In the operation of reeling, it is well known, that if the thread be wound separately it will be totally unfit for the purposes of the manufacturer; consequently the ends of the threads of several balls or cocoons are joined and wound together, and when any one of them breaks or comes to an end, its place is supplied by a new one, and thus by continually keeping up the same number the united threads may be wound to any required length.

The reeling is conducted by a woman, who, when the balls or cocoons have remained a sufficient time in the hot-water contained in the boiler A, to soften the gum, takes a whisk of birch or rice-straw, about six inches long, cut stumpy like a worn-out broom, and brushes the cocoons with it, which causes the loose threads to adhere to it; these she disengages from the whisk, and by drawing them through her fingers cleans them from the loose silk, which always surrounds the cocoon, till they come off clean, which operation is called *la battue*. When the silk has been perfectly cleansed, she passes four or more of the threads, if she intends to wind fine silk, through each of the holes in the thin iron bar H, and afterwards twists the two compound threads, consisting of four cocoons each, about 20, or 25 times round each other, that the four ends in each thread may the better join together by crossing each other, and that the thread of the silk may be round, which otherwise would be flat.

The threads when thus twisted together are passed through the eyes of the loops, C, of the layer, and thence are conducted and made fast to one of the rails of the reel. As it is of consequence in the production of good silk, that the thread should have lost part of its heat and gumminess before it touches the bars of the reel, the Piedmontese are by law obliged to have 38 French inches between the guides, C, and the centre of the reel; and the layer must also, under a penalty, be moved by cog-wheels instead of an endless cord, which, if suffered to grow slack, will cause the layer to stop and not lay the threads distinctly, and that part of the skein will be glued together, whereas the cog-wheel cannot fail: when the skeins are quite dry, the reel is removed from the frame, and by the folding of two of its arms, by means of hinges, the skeins are taken off, and with some of the refuse silk are tied into hanks.

Although from the foregoing description the operation must appear very simple, it is a matter of very great nicety to wind an even thread, and the difficulty of keeping the thread always even is so great that, except when using a thread of two cocoons, they do not say a silk of three, four, or six cocoons; but a silk of three or four, four or five, five or six cocoons. In a coarser silk it cannot be calculated even so nearly as to four cocoons, and consequently they say, from 12 to 15, from 15 to 20, and so on.

It is also necessary that the water in the boiler be kept at a certain temperature; for if the water is too hot, the thread is dead and has no body; if too cold, the ends of the threads do not join well, and form a harsh silk. The threads themselves indicate when the water is not at the proper degree of temperature, by frequent breaking when it is too hot; and coming off entangled, and in a woolly state when too cold.

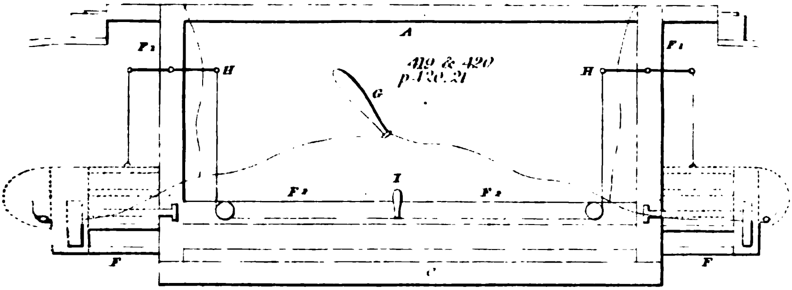
In the process of winding the woman has always a bowl of cold water by her, into which she occasionally dips her fingers, and frequently sprinkles it upon the iron bar H, that the threads may not be burnt by the heat of the basin; it also serves to lessen the temperature of the water in the boiler when approaching the boiling point.

All kinds of silk which are simply drawn from the cocoons by the process of reeling are called raw silk, and is denominated coarse or fine according to the number of fibres of which the thread is composed. In preparing the raw silk for

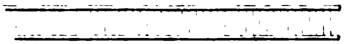
WEAVING

From 417 to 423

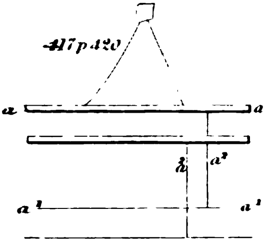
419 & 420 p 420.21



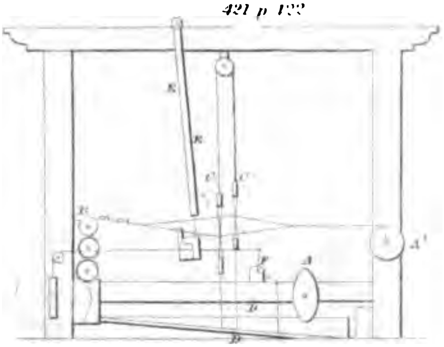
418 p 420



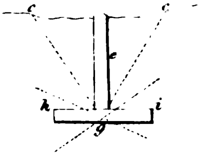
417 p 420



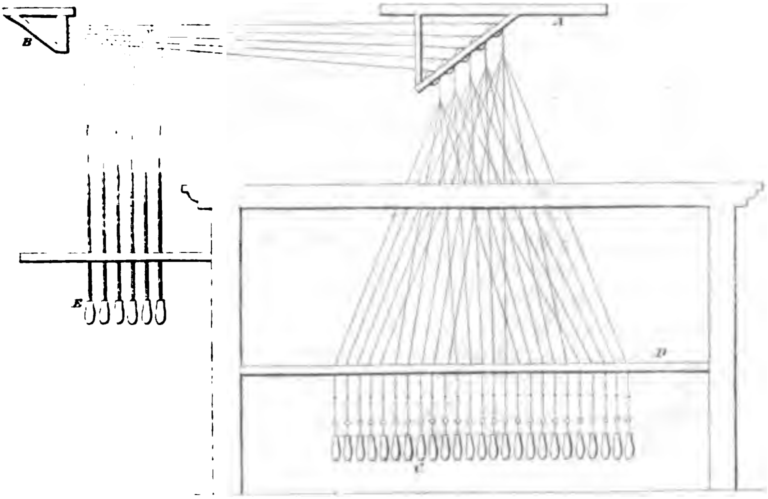
421 p 422



422 p 422



423 p 423



dying, the thread is slightly twisted, in order to enable it to bear the action of the hot liquor without the fibres separating or furring up. The silk-yarn employed by the weavers for the woof or weft of the stuffs which they fabricate, is composed of two or more threads of the raw silk, slightly twisted by the aid of machinery; and the thread employed by the stocking-weaver is of the same quality, but composed of a greater number of threads, according to the thickness required.

Organzine silk consists in combining together two or more threads of silk, each of which has in the first instance been twisted by itself, and afterwards the whole are twisted together. This operation, with the exception of the elongation of the cotton, closely resembles roving in the Cotton Manufacture. The process consists of six different operations. 1. The silk is wound from the skein upon bobbins in the winding-machines. 2. It is then sorted into different qualities. 3. It is spun or twisted on a mill in the single thread, the twist being in the direction of from right to left, and more or less tight, as the purposes to which the silk is to be applied may require. 4. Two or more threads thus spun are doubled or drawn together through the fingers of a woman, who at the same time cleans them, by taking out the slugs which may have been left in the silk by the negligence of the foreign reeler. 5. It is then thrown by a mill, that is, two or more threads are twisted together, either slack or hard, as the manufacturer may require; but the twist is in an opposite direction to the first twist, and it is wound at the same time in skeins upon a reel. 6. The skeins are sorted according to their different degrees of fineness, and then the process is complete.

The first operation which the raw silk undergoes is winding, that is, drawing it off from the skeins in which it is imported, and winding it upon wooden bobbins, in which state it can go to the other machines.

Each of the skeins is extended upon a slight reel called a swift; it is composed of four small rods, fixed into an axis, and small bands of string are stretched between the arms to receive the skein, but at the same time the bands admit of sliding to a greater or less distance from the centre, so as to increase the effective diameter of the reel, according to the size of the skeins, because the skeins, which comes from different countries, vary in size, being generally an exact yard, or other similar measure, of the country where the silks are produced. The swifts are supported upon wire pivots, upon which they turn freely when the silk is drawn off from them;

but in order to cause the thread to draw with a gentle force, a looped piece of string or wire is hung upon the axis withinside the reel, and a small leaden weight is attached to it, to procure friction. The bobbins which draw off the threads are received in the upper part of the frame, and are turned by means of a wheel beneath each, the bobbin having a small roller upon the end of it, which bears by its weight upon the circumference of the wheel, and the bobbin is thereby put in motion to draw off the silk from the swift. A small light rod of wood, called a layer, which has a wire eye fixed into it, is placed at a little distance from, and opposite to, each bobbin, so as to conduct the thread thereupon; and as the layer moves constantly backwards and forwards, the thread is regularly spread upon the length of the bobbin. The motion of the layer is produced by a crank fixed upon the end of a cross-spindle, which is turned by means of a pair of bevelled wheels from the end of the horizontal axle, upon which the wheels for turning all the bobbins are fixed.

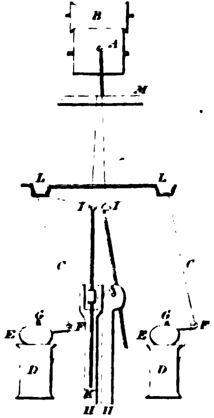
These winding-machines are usually double, to contain a row of bobbins and swifts at the back as well as in front. Two of these double frames are put in motion by cog-wheels from a vertical shaft, which ascends from the lower apartments of the mill, where the twisting-machines are placed. The winding-machines require a constant attendance of children to mend the ends of threads which are broken; or when they are exhausted, they replace them by putting new skeins upon the swifts. When the bobbins are filled, they are taken away, by only lifting them up out of their frame; and fresh ones are put in their places.

A patent has been lately taken out by Messrs Gent and Clarke, for a new construction of the swifts for winding-machines: they are made with six single arms, instead of four double ones; and the arms are small flat tubes made to contain the stems of wire forks, which receive the skein, instead of the bands of string in the common swifts. These forks admit of drawing out from the tubes until the swift be sufficiently enlarged to extend it; but as they extend the skein at six points instead of four, as in the common ones, the motion is more regular. Instead of the weight which causes the friction, a spring is used to press upon the end pivot of the axis, and make the requisite resistance.

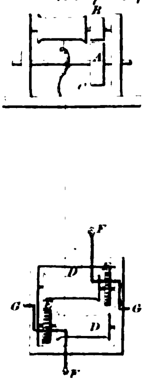
The twisting of the silk is always performed by a spindle and bobbin, with a flyer, but the construction of the machine is frequently varied. The limits of our plate do not admit a representation of the great machines, or throwsting-mills,

From 424 to 430.

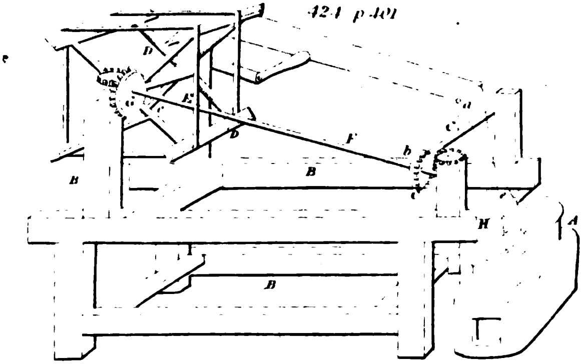
429 p 406



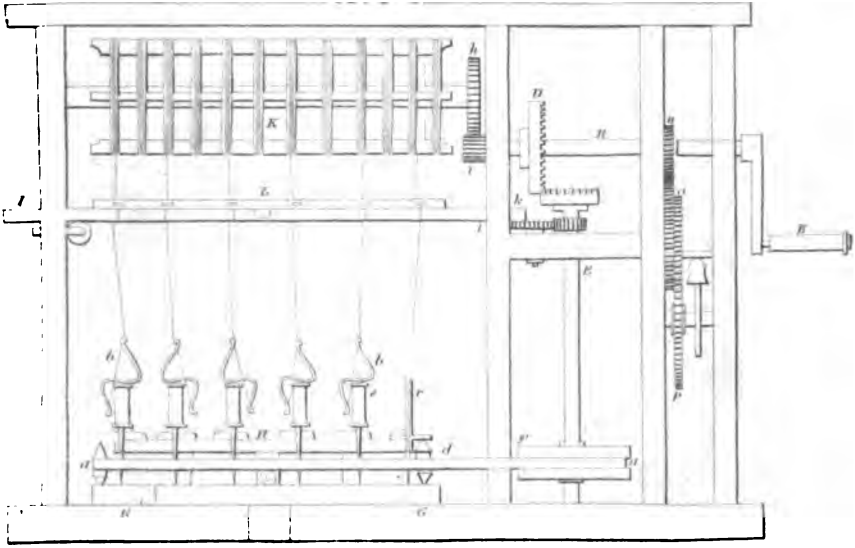
430 p 407



424 p 401



426 p 405.6



at their full extent; but the principle is the same as fig. 426, which we have extracted from Dr Rees's Cyclopædia, varying the description a little, to agree with the present improved state of the manufacture.

In fig. 426, we have given a drawing of a small machine, which is similar in the parts which act upon the silk; and indeed many mills employ such machines constructed on a large scale. The one in our plate contains only thirteen spindles, and is intended to be turned by hand, a method which is too expensive for this country, but is common in the south of France, where many artisans purchase their silk in the raw state, and employ their wives or children to prepare it by these machines, which they call *ovales*, because the spindles, *b b*, are arranged in an oval frame, G H.

B is the handle by which the motion is given; it is fixed on the end of a spindle R, which carries a wheel D, to give motion to a pinion upon the upper end of a vertical axle E; this, at the lower end, has a drum or wheel F, to receive an endless strap or band, *a a*, which encompasses the frame G, and gives motion to all the spindles at once. The spindles *b b* are placed perpendicularly in the frame G H, their points resting in small holes in pieces of metal, which are let into the oval plank G; and the spindles are also received in collars affixed to an oval frame H, which is supported from the plank G by blocks of wood; *d* and *a* are small rollers supported in the frame G H, in a similar manner to the spindles; their use is to confine the strap *a*, to press against the rollers of the spindles with sufficient force to keep them all in motion.

The thread is taken up, as fast as it is twisted, by a reel K, which is turned by a wheel *h*, and a pinion *i*, upon the end of the principal spindle R. The threads are guided by passing through wire eyes, fixed in an oval frame L, which is supported in the frame of the machine, by a single bar or rail *l l*, and this has a regular traversing motion backwards and forwards, by means of a crank or eccentric pin R, fixed in a small cog-wheel, which is turned by a pinion upon the vertical axis E; the opposite end of the rail *l* is supported upon a roller, to make it move easily. By this means the guiders are in constant motion, and lay the threads regularly upon the reel K, when it turns round, and gathers up the silk upon it as shown in the figure.

One of the spindles is shown at *r* without a bobbin, but all the others are represented as being mounted and in action. A bobbin, *e*, is fitted upon each spindle, by the hole through it being adapted to the conical form of the spindle, but in such manner that the bobbin is at liberty to turn freely round upon the spindle; a piece of hard wood is stuck fast upon each spindle, just above the bobbin, and has a small pin entering into a hole in the top of the spindle, so as to oblige it to revolve with the spindle; this piece of wood has the wire-flyer, *b*, fixed to it; the flyer is formed into eyes at the two extremities; one is turned down, so as to stand opposite to the middle of the bobbin *e;* and the other arm, *b*, is bent upwards, so that the eye is exactly over the centre of the spindle, and at a height of some inches above the top of the spindle. The thread from the bobbin, *e*, is passed through both the eyes of this wire, and must evidently receive a twist when the spindle is turned; and at the same time, by drawing up the thread through the upper eye, *b*, of the flyer, it will turn the bobbin round, and unwind therefrom. The rate at which the thread is drawn off from the bobbin, compared with the number of revolutions which the flyers make in the same time, determine the twist to be more or less hard. This circumstance is regulated by the proportion of the wheel *h* to the pinion *i*, from which it receives motion; and these can be changed when it is required to spin different kinds of silk.

The operation of the machine is very simple. The bobbins filled with silk in the winding-machine, fig. 425, are put loose upon the spindles at *e*, and the flyers are stuck fast upon the top of the spindles; the threads are conducted through the eyes of the flyers *b*, and of the layers L, and are then made fast to the reel K, upon which it will be seen that there are double the number of skeins to that of the spindles represented, because one-half of the number of spindles is on the opposite side of the frame, so that they are hidden. With this preparation the machine is put in motion, and continues to spin the threads by the motion of the flyers, and to draw them off gradually from the bobbins, until the skeins upon the reel are made up to the requisite lengths. This is sometimes known by a train of wheel-work at *n o p*, consisting of a pinion, *n*, fixed upon the principal spindle R, turning a wheel, *o*, which has a pinion fixed to it, and turning a large wheel *p*; this has another wheel upon its spindle, with a pin fixed in it, and at every revolution raises a hammer and strikes upon a bell, *s*, to inform the attendant that the skeins are made up to a proper length.

In the silk-mills they employ two different machines, one for the first operation on organzine, and the other for the second operation.

Thus, after the silk is twisted it must be wound on fresh bobbins, with two or three threads together, preparatory to twisting them into one thread. In the original machines at Derby this was done by women, who, with hand-wheels, wound the threads from two or three of the large bobbins upon which the silk is gathered instead of the reels, and assembled them two or three together upon another bobbin, of a proper size to be returned to the twisting-mill.

In 1800, Mr John Sharrar Ward, of Bruton, obtained a patent for a new method of doubling silk, worsted, cotton, or flax, which we intend to describe here; for though various modes are adopted for this purpose, one will be sufficient to give an idea of the whole. Whatever number of threads may be required to be doubled together, they may by means of this invention be doubled to the greatest certainty; for if at any time any one of the threads, or union of threads, to be so doubled, should break, it will immediately stop the other thread or threads until the broken thread shall be repieced, which secures a constant double thread, or union of threads; and the manner in which the same is to be performed will, we trust, be clearly understood by the subjoined description.

Fig. 429. A is a roller carrying round the bobbin B, which draws the threads C C from the bobbins D D; consequently the balls E E, and the thread-wires F F, move round on the pins G G. H H are two wood or iron standards, at the tops of which are hung two regulating thread-wires, I I. When either of the threads C C break, the thread-wire through which it passes falls down, and the tail part K rises up to a level with the ball E, and stops the other head-wire from going round, and consequently the thread

that passes through it, and prevents the bobbin B from taking it up; but the roller A continues its motion. L L are guide-wires for the threads to pass over; M is a slide, moved by a short wheel or crank, to lay the threads level on the bobbins.

Fig. 430 is another doubling-machine, the form varied, but the principle the same as fig. 429. A is a roller, whereon lies a smaller one, marked B, the axis of which goes through the bobbin; C is a slide, for the same purpose as M, in fig. 429; D D two bobbins, with spindles through them, on each of which is fixed a wheel E E; F F are two thread-wires hung at G G. When either of the threads break, the wires drop between the teeth of the wheel, and stop the other thread, the bobbin and roller B stopping at the same time; but the roller A continues moving, as A in fig. 429.

The bobbins being thus filled with double or triple threads, are carried back to the throwsting-machine, and are there spun or twisted together in a manner similar to that before described. At this period, the silk is a marketable article, and is passed from hand to hand.

The silk being now spun, is put into a boiler filled with hot water, into which is put a small quantity of soap, in order to divest the silk of its gum. In the earlier processes, the gum was necessary for the purposes of the manufacture, for the silk, had it been divested of it, would have assumed a fine downy appearance similar to that of cotton, and must have undergone similar operations before it could have been formed into a thread ; this, indeed, is necessary for that portion of waste silk which is drawn from the cocoons in the first operation of reeling ; also for those cocoons which have been reserved for breed, or which is made in the operations of twisting just mentioned, through which the moth or butterfly has eaten a hole, and rendered them impracticable to be wound off into silk.

The silk is now taken to the warping-mill, which, being a precursor to the act of weaving, will be noticed under that head.

At this present moment several improvements are in progress for winding and throwing silk upon a new principle: indeed, the silk manufacture now may be compared with what the cotton manufacture was about thirty years ago. There appears to be taking place in every department the same great and rapid improvements; and it is much the opinion of practical men, that the machinery now in use will, in the course of a very few years, be entirely superseded, and that this branch of our manufactures will ultimately be almost, if not quite, as great a source of national prosperity as the cotton manufacture.

The art of throwing silk was first introduced into this country by Mr John Lombe, who, with considerable ingenuity, and at the risk of his life, took a plan of one of these complicated machines in the king of Sardinia's dominions, from which, on his return, he, in conjunction with Mr Thomas Lombe, established a similar set of mills at Derby. Parliament granted them a patent for fourteen years; and, on being petitioned at the end of that term for a renewal, granted them 14,000*l.* instead, on condition that they should allow a perfect model to be made, and placed in the Tower for public inspection.

FLAX MANUFACTURE.

Flax undergoes various processes before it can be worked into cloth or other articles; these processes are very different, and require different sorts of implements and machinery, in order to their being properly performed. Flax, for the purpose of being formed into cambric, fine lawn, thread, and lace, is dressed in rather a different manner to that which is employed for other purposes; it is not scotched so thoroughly as common flax, which from the scotch proceeds to the heckle, and from that to the spinner; whereas this fine flax, after a rough scotching, is scraped and cleansed with a blunt knife upon the workman's knee, covered with his leather apron; from the knife it proceeds to the spinner, who, with a brush, made for the purpose, straightens and dresses each parcel before she begins to spin it.

In the *Swedish Transactions* for the year 1747, a method is given for preparing flax in such a manner as to resemble cotton in whiteness and softness, as well as in coherence; for this purpose, a little sea-water is directed to be put into an iron pot, or an untinned copper kettle, and a mixture of equal parts of birch-ashes and quick-lime strewed upon it; a small bundle of flax is to be then opened and spread upon the surface, and covered with more of the mixture, and the stratification continued till the vessel is sufficiently filled. The whole is then to be boiled with sea-water for ten hours, fresh quantities of water being occasionally supplied in proportion to the evaporation, that the flaxy matter may never become dry. The boiled flax is to be immediately washed in the sea, by a little at a time, in a basket, with a smooth stick at first, while hot; and when grown cold enough to be borne by the hands, it must be well rubbed, washed with soap, laid to bleach, and turned and watered every day for some time. Repetitions of the washing with soap expedite the bleaching; after which, the flax is to be beat, and again well washed; when dry, it is to be worked and carded in the same manner as common cotton, and pressed between two boards for forty-eight hours. It is now fully prepared and fit for use. It loses in this process nearly one-half its weight, which, however, is abundantly compensated by the improvement made in its quality, and its fitness for the finest purposes.

The treatment of flax and hemp from the time of their growth up to their formation into thread and cloth is so very similar, that a description of the operations performed on the one will answer for both; we shall therefore, under this present article "Flax," give a description of the new mode of obtaining flax and hemp from the plant; and under Rope Manufacture, describe the former slow, injurious, and expensive process of dew-retting or water-steeping.

This improved process was first carried into practice by Mr James Lee, who has discovered that, when the hemp or flax plants are ripe, the farmer has nothing more to do than to pull them as heretofore practised, and spread and dry them in the sun as he would his hay or grain, taking care only in the ridges to lay the roots in one direction, so as to prevent, as much as possible, the breaking or entanglement of the stems, and when sufficiently dry, to carry them and lay them in store, either in ricks or in barns.

The stalk of the flax-plant when it has been thus pulled and dried, can be separated into two principal component parts or substances, namely, an internal pith, and an extraneous fibrous covering; the pith, or brittle matter, is technically called "boon;" and the fibrous covering, "harle" or "fibre." The operation of detaching the boon from the fibre is called "breaking of flax."

Various machines have been invented for the breaking of flax, some of which we shall proceed to describe, commencing with those by Mr Bundy. Mr Bundy's machines are a breaker and a rubber. The first being for the purpose of separating the harle from the boon, the latter for rubbing and subdividing the fibres, and finally cleansing it before it goes to the heckler. The breaking machine will be first described, as it is to be first used, and it will appear that although it consists chiefly of fluted or toothed cylinders, yet it varies from all other machines for the same purpose which have preceded it, by the inequality of the depth of its teeth, the play or space which exists between one tooth and another, and in the reciprocating motion of the cylinders combined with their progressive motion, instead of its being progressive only as in all former cases: by these means the happiest effects are produced. The simple manner in which this complex motion is brought about reflects the highest credit on the mechanical skill of Mr Bundy, the inventor not only of these machines but of many others of equal ingenuity.

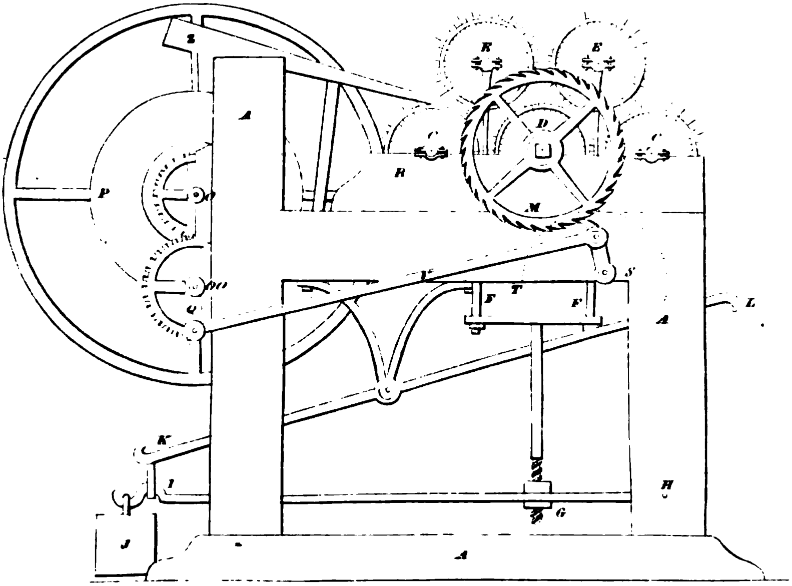
Fig. 432, represents a side view of the breaking machine, on a scale of three-quarters of an inch to a foot. The framing, A, is of timber, which serves to support the five breaking cylinders, C C D E E, turning on pivots. C D and C move in cross bearings, fixed upon the boards or supports B, on the two opposite sides of the machine, while E E merely lay above and between C D and D C, and are drawn down to these by two rods, as seen at F F. The lower ends of these are joined by a connecting bar, and another rod proceeds downwards, its lower end fixed by a double adjusting nut G, near the pin or fulcrum H, of the lever or presser H I, which is loaded with a weight J. There is a similar lever on each side of the machine, to bear down the four ends or pivots of the two rollers E E, and the ends of these levers, nearest I, are united with a cross bar, by means of which one weight, J, acts on them both, and is made to press equally by an adjusting nut or screw, on each side, like G. K L is a level placed under the machine, one end of which is attached to the weight J, in such a manner that by pressing down its end L, I is raised, and all pressure is instantly prevented between the superior cylinders E E and those under them at C D C, for stopping the operation of the machine at any time. The breaking cylinders are about eighteen or twenty inches in length, and are made of beech, or any hard wood, and are all similar to each other in dimensions, and in having breakers which act also as teeth, extending like projecting plates their whole length, parallel to the axis. These breakers, or teeth, are formed of thin hoop-iron, let about half its width into saw-cuts in the cylinder, into which they are driven, and they are retained in their places by iron hoops put on to each end of the cylinders; they are about half an inch asunder, their external edges are well rounded, so as not to cut the flax, and they are alternately long and short; the long or deep teeth projecting about three-quarters of an inch from the cylinder, while the short ones are about half that length. In placing the lower breaking cylinders in their places, care must be taken that they do not touch each other, since their teeth are only to connect through the medium of the two upper rollers which press upon them. The axis of the roller D is longer than the others, and extends on both sides beyond the frame, and upon each end of it is fixed a cast-iron wheel, by which motion is to be given to the cylinder, and through this to all the others. Both of the wheels are of the same diameter; but one is a ratchet-wheel, as will be seen in the last figure, while that on the opposite side is a spur, or common toothed wheel, as will be seen in fig. 433, which represents such parts of the machine on the opposite side as are essential to its motion, and the same letters of reference are used in both figures to denote similar parts.

The first motion is given to this machine from the iron spindle O, fig. 432, which may be turned by a handle or by a bond and rigger, as at P. It may also be connected with a pair of spur-wheels and a fly, as shown in fig. 432, to assist its motion. On each end of the lower spindle, if two are used, there is a crank, as at Q, attached to a connecting rod V, the opposite end of which in fig. 432, is attached to a pall or lever turning on a centre S, so that when V, or D D, is turned, the end of this lever will describe a portion of a circle, shown by the dotted line T A, and will engage with the ratchet teeth of the wheel M, and carry it partly round;

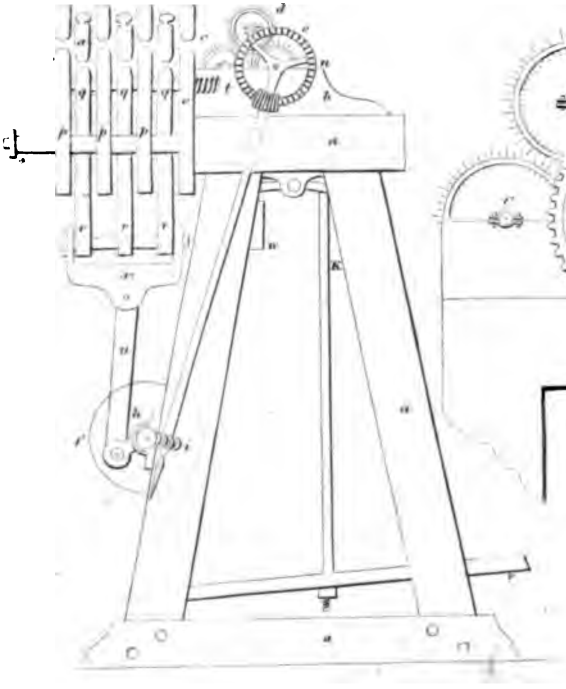
FLAX MANUFACTURE

Plate 61.—From 432 to 434.—Page 410

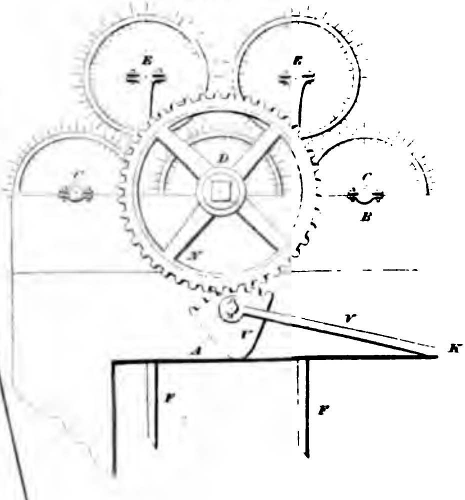
432



434



433



while on the other side of the machine, shown in fig 433, the connecting rod K, passes from the crank of V, to a toothed segment U, the teeth of which work into the teeth of the spur-wheel N, fixed upon the opposite gudgeon of the breaking cylinder D. The connecting rod on this side of the machine, must be so adjusted in length, that in its motion outwards, the end tooth of U, next to A, must be withdrawn out of the teeth of the wheel N, but that when it moves in a contrary direction, or from T towards A, it must move completely in the teeth of the wheel, and not leave them, and, of course, N, at this time, is incapable of any other motion but what the segment U also has.

The connecting rod Q V, in fig. 432, must also be adjusted in length to the pall or gathering-tooth S, as to make it continue to act upon its wheel M, for the space of one tooth of N, in fig. 433, after the segment U has been withdrawn from its wheel N; and thus, although the motion of U, would produce a backward and forward motion of its corresponding wheel N, and the breaking cylinder D, and consequently of all the other cylinders, yet by the after action S upon M, the roller D, and its wheel N, are made to advance gradually by the space of one tooth of K, for every revolution of O, and thus a slow but regular progressive motion of the cylinder is obtained at the same time that the vibratory or oscillating motion is going on. The flax is fed or supplied in handsfull on the feeding-trough Z, and pressing it gently between the rollers C and E, and it is delivered out from between the rollers E and C, at the end of the machine, next to L, in a sufficiently clean and divided state to enter the rubbing-machine, which will be next described. The superiority of this machine over common fluted rollers needs no comment, since the distance between the teeth and the skate, which is produced by the alternating motion of the cylinders, exactly gives that action which is best suited to break off and disengage the bark and woody matter, which, when dry, is quite brittle, and falls to the bottom of the machine. Once passing the rollers is in general sufficient for either flax or hemp stalks, but the work is rendered more perfect by a second passage through them, which does not at all injure the fibre.

The rubbing machine, which is to be used immediately after the above breaking process, is represented in a side view, or rather section, in fig. 434.

In this, *a* is in the wooden frame for supporting the machine, *b*, the bearers for the three rollers *c*, *d*, *e*, are disposed as in the breaking machine, but in this case they are only for the purpose of drawing or leading the flax through the machine, (the breaking being presumed to have been already done by the last described or any other process,) they must be fluted, or grooved, or may be made in the same manner as the breaking cylinders, but with the teeth of equal length, much shorter, and of a finer gauge or pitch: *f*, is a rigger or pulley, to which a rapid circular motion is to be given; it is hung upon a shaft or spindle, turning in brass bearings, and fixed to the frame *a*; on the end, *h*, of this spindle, is formed an endless screw, or worm, which turns a small wheel, *i*, fixed upon the lower end of an iron spindle, K, turning in bearings, and leading by a bevel pinion at its upper end to the face-wheel *n*, which is fixed on one of the gudgeons of the fluted or toothed roller *e*, so that whenever the rigger *f*, is turned, even with a rapid motion, a very slow motion will be communicated to the rollers *c*, *d*, *e*. The most essential part of this machine consists of the rubber-boards, *o*, *p*, *q*, *r*. Their edges or sections can only be seen in this representation, but their length may be from eight inches to a foot or more. The board *o*, is firmly fixed on the top of the framing *a*, and is without motion, while those marked *p p p*, are supported upon the two strong cylindrical iron pins *s*, which are firmly screwed into the frame *a*, and pass through holes which fit them in the boards *p p p*, so that these last can be moved to a greater or less distance from each other, but are incapable of up and down motion. The intermediate boards, *q q q*, are so much shorter as to pass between the iron pins *s*, and admit of an up and down motion between *p p p;* for this purpose they are all connected together by an iron link or staple, *x*, fixed upon the top of the connecting rod, *u*, the lower end of which works upon a crank in the middle of the first spindle, upon which the rigger *f* is placed, so that in every revolution of *f*, the movable boards *q q q* are driven upwards and downwards between the more stationary boards *p p p*, and the one which is fixed at *o*. The whole of the boards are drawn towards *o*, by means of a rod on each of their sides passing through *p p p* and *o*, and acted upon at *f* by weights or spiral wire springs, and the whole of the boards are perforated with a slit or mouth, from four to six inches long, (according to their width) and about a quarter of an inch wide, placed near their tops, at an equal distance from the top of each, and nicely rounded off on all its edges. The consequence will be, that whenever the crank is in an horizontal situation, all these slits will coincide, but when the crank is down, as in the figure, the slits in *q q q* (which slits are seen only in section) will be below those in *p p p* and *o*, while, when the crank is up, they will be elevated above them; and thus it will easily be perceived that if flax, or any other flexible material, is passed through the slits in the boards when they do coincide, and then conducted between the toothed rollers, that while these are drawn slowly on through the machine, the boards *p p*, *q q*, &c. by their rapid up and down motion, will effectually rub it, and cleanse it from any extraneous matter which may adhere to it, as well as open the fibres; and for the better regulation of this operation, *v* is a treadle, or lever, near the foot of the attendant, by pressing on which, the weight *w*, which depresses the top roller *d*, will be raised, in consequence of which the rollers will cease to draw, although the rubbing still continues, so that its velocity in passing the machine may be correctly regulated, at the will of the superintendant.

For the purpose of setting this machine to work in the first instance, and charging it with flax, the tops of all the rubbing-boards are movable, and made to separate through the slits which are made in them, for which purpose they are attached at one end by strong hinges, and are fixed down at the other by the thumb-screws, which are shown in the figure, or by any other sufficient fastenings. It will, however, only be necessary to open them on first setting them to work, since all future quantities of flax to be rubbed may be tailed on to that which is already in the machine. The flax is to be supplied by placing it on a perpetual revolving cloth or feeding table, joined to the ends of the machine, and worked by connexion to some of its wheels; but this is not shown in the figure, as it forms no part of the invention, and is common in all cotton and flax-manufactories.

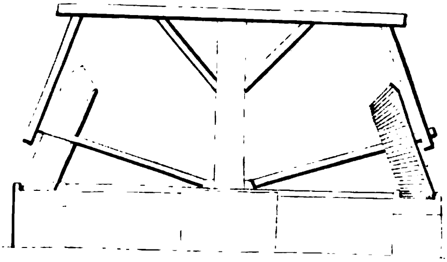
In April 1819, Mr Bundy obtained another patent for other machinery for effecting the same objects. This machinery is represented by fig. 435.

A A A A is the frame of the machine supporting the two conical rollers B and C, which revolve freely and independently of each other, or without touching, having iron or steel axles at both their ends, which are

FLAX MANUFACTURE

Plates 62 & 63. From 435 to 449. Page 413

436



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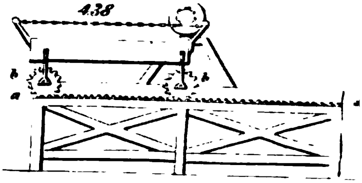

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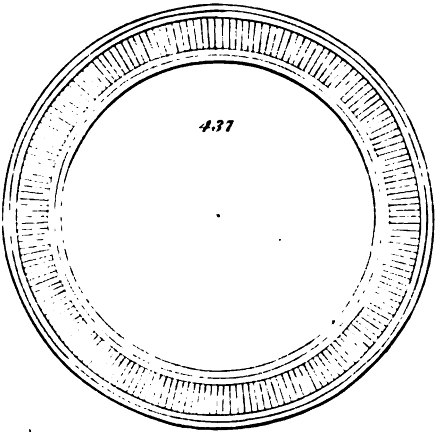

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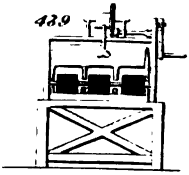

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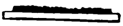
441



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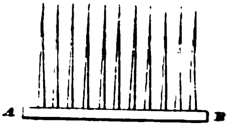

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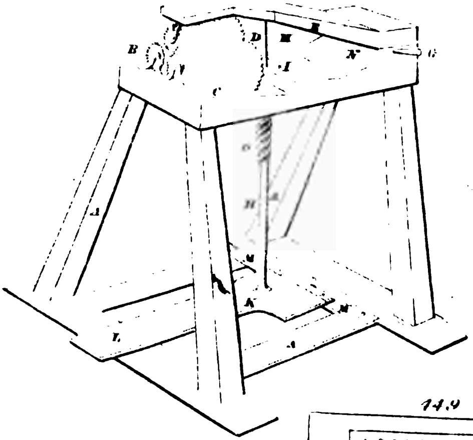
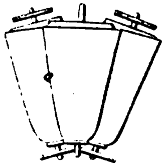
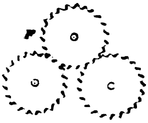
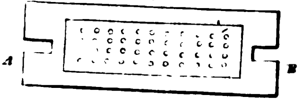






449



supported in brass or other proper carriages, as shown in the figure. A third conical roller, D, is supported by similar carriages, under the top piece E.

The aforesaid three rollers B, C, and D, are all similar in construction, dimensions, and shape, being all frustra of cones, with flutes or longitudinal teeth in their external conical surfaces. It is not, however, essential to the performance of the machine, that they should be all of the same dimensions, provided they are so fixed in their carriages that the teeth or flutes upon the upper roller may take into and act with those of the two lower ones: and that they will all move or revolve together when the upper roller, D, is incumbent upon, or lies between, the two lower rollers, B C, as shown in the figure, and in the plan at Q. These rollers may be made of metal, and cast with the teeth of the form shown in the detached figure F, which is a section through the widest ends of these conical rollers, not only to show the form of teeth which will be most convenient when the rollers are to be cast, but also the nature of their contact when the upper roller, D, is depressed between the two lower ones.

The form of tooth shown at F, is not, however, essential to the perfection of this machine, since the rollers may be made of wood, having strips of metal let into grooves cut in such wood, while the outer edges of such strips are rounded, and left projecting above the surface of the same, and these will answer quite as well as the form of tooth shown at F. It must nevertheless be observed, that whatever form of tooth be adopted, the teeth must be so shaped and disposed with regard to each other, as to have considerable play between them in order to admit the flax-stem which is intended to be broken and prepared.

The upper piece, E, of the machine, which carries the upper conical roller, D, is fixed or attached to the main frame, A A A A, by strong hinges, or any other movable joint, at G, and a rod of iron, or other sufficiently strong material. H H is attached at its upper end by a joint to the top piece, E, passes through a hole near I, and is fixed at its lower end by another joint, K, to the treadle or lever, K L, which turns upon the joint or hinges M M. A spring or weight (the patentee prefers the former,) is applied to the machine in such manner, that its action will always keep the upper piece, E, and, consequently, the upper roller, D, in an elevated or raised position above the lower rollers, B and C, when the machine is not in action, and of course the end L, of the treadle, will also be raised, which admits of the flax being introduced between the rollers, viz. over the two lower rollers, B and C, and under the upper roller, D, and a spring may be applied in a variety of ways, such as between the top piece E, and the top or platform of the machine at N; or it may be a strong spiral wire spring, having its upper end fastened to the platform, while its lower extremity is fixed to the rod H H, round which it coils, as at O, or it may be placed under the end, L, of the treadle; but in every case its strength must be no more than will be sufficient to raise the upper roller, D, about two inches from the lower rollers, otherwise it will occasion unnecessary fatigue to the person working the machine.

The manner of using the machine is as follows:—The upper and lower rollers being separated as aforesaid, a small handful of dried flax or hemp-stems is to be introduced between them, and held extended by the two hands while the rollers are brought together by the pressure of the foot upon L. While that pressure is continued, the flax or hemp is to be drawn backwards and forwards, by the hand, between the rollers in a direction at right angles to the axis of the rollers, and eventually withdrawn by pulling with one hand only. The foot is now to be removed until the flax or hemp is again replaced; and each end is in this way to be drawn several times through the machine until such ends are respectively finished.

By a succession of these operations (using the pressure of the foot upon L), each time that the flax or hemp is introduced between the rollers, (and regulating such pressure according to the process of the work), the flax or hemp will soon be sufficiently worked, and the fibre brought into a sufficiently clean and divided state for bleaching; or if it be required to spin it in the yellow state, it may be made sufficiently fine by a longer continuation of the same process, particularly if worked between the smaller ends of the rollers.

Indeed, it is recommended that the operation should, in all cases, be commenced and continued for some time with the larger part of the rollers, and finished with their smaller ends. In this point of view, the invention of conical rollers will be found of great importance and use; for as the flutes, grooves, or teeth, vary in their distance from each other at all points between the large and small ends, so it becomes almost impossible for the workmen to draw the flax or hemp through such rollers in the same track; and thus the breaking of the boon must be much more irregular, and the fibre will be much more effectually cleansed than it can be by the flutes, grooves, or teeth of the cylinders, or other contrivances in former use.

The reader being now acquainted with Mr Bundy's inventions for the breaking of hemp and flax, we shall next proceed to detail the modes resorted to for the effecting of the same objects by Mr James Lee.

Mr Lee's method consists of four parts.

The machinery of the first or that part of the invention which relates to the breaking of the flax, is shown by fig. 436, and fig. 437. Fig. 436 represents the section of a mill-bed, and fig. 437 a plan of the same. The bed of the mill should be constructed of cast-iron, or any other fit material, raised on masonry or brickwork, or by any other eligible mode of setting. This bed is to be cast or cut into grooves, flutes, notches, or teeth, in a radiant direction from the centre. Into, or upon, this bed, is placed one or more rollers with grooves, flutes, notches, or teeth, corresponding to those of the bed. These rollers should be of very great weight, perhaps a ton each, and revolve round the bed by means of their axles, which are connected with machinery similarly to the ordinary construction of mills, and motion should be given by any of the usual powers usually applied to such purposes.

The flax, hemp, or vegetable fibrous substances, being quite dry, should, in a raw state, be laid in or upon this bed, and submitted to the operation of bruising or crimping by the pressure of the rollers, which are made to pass over it till the woody particles are separated from the fibre.

Another mode of breaking, invented by Mr Lee, may be seen in fig. 438, which is a side view of the machine.

a a is the bed with indentations as before described; and *b b* rollers, of which there may be several, with teeth corresponding with those of the bed. The axes of these rollers are attached to a box, intended to carry a considerable weight; and the flax or hemp is laid in the bed, and operated upon by the box and rollers traversing over it, and producing the effect of breaking the woody parts from the fibre. When the box has travelled to one end of the bed, the flax or hemp may be removed from the other end when sufficiently broken, and the bed be replenished with a fresh supply. The alternate traversing motion is produced on the same principle as that applied to Baker's horizontal mangle.

Fig. 439 is an end view of the same machine, showing two beds. The dimensions of this last machine, the patentee proposes, should be about six feet six inches long in the bed, calculated to hold two lengths of flax at the same time, so that when the box and rollers are at one end, the flax may be removed at the other, and fresh flax be placed ready for the rollers in returning to operate upon. But in cases of hemp or other vegetable fibrous substances, longer than the usual length of flax, one end only can be operated upon at a time. The rollers he proposes should be made from eight to fourteen inches in length, and their diameter not be less than four inches. The process of scraping off the wooden particles is effected by the machine called a scraper, and described in the specification of the patentee's former patent, dated 5th December 1816.

The second part of the invention, that is to say, the discharging of the coloured matter out of the flax, hemp, or other vegetable substances, the patentee performs by means of either of the machines before described for breaking, although he gives preference to the plain rollers, for the purpose of discharging the colour out of the unsteeped flax or hemp, after they have been broken and scraped free from the woody particles. To effect this, a stream of water is allowed to flow into the bed whereon they are laid, and the rollers being put into action upon them, the coloured matter is squeezed out. It should be observed, that the sides of the bed must be raised so as to form a trough, in order to hold the water. This operation is commenced with cold water, and when that has been drawn off, the bed is replenished with warm water, into which a certain quantity of soap has been dissolved. This soap and water may be supplied by a pipe from a boiler, and the operation may be continued till the water is at the boiling heat, by which time the flax or hemp will have lost the coloured matter, and have become perfectly soft and white; after which it must be washed and made perfectly dry, and submitted to the action of the first mentioned breaking machine.

The third part of Mr Lee's invention consists of a mode of dividing flax, hemp, or other vegetable fibrous substances, when prepared as above, and carefully hackled into equal lengths, so that each length may be operated upon with greater advantage by the roving machinery now in use. In order to effect this, Mr Lee provides a board, eighteen inches long and five inches wide, seen lengthways in fig. 440, and an end view in fig. 441. On the board, at three or four inches apart, he places single rows of comb or hackle-teeth, and upon this he lays the flax, hemp, &c., and, placing small weights to keep them flat, draws out the longest ends by hand, laying them in distinct parcels according to their respective lengths; he then reverses the piece of flax, hemp, &c. and pursues the same course with the opposite end.

The fourth part of the invention is to draw the flax or hemp into a state which may be spun upon machinery, sufficiently fine for the fabrication of cambric, lace, and equally fine articles. To effect this, Mr Lee provides an apparatus similar to the last, only the teeth are much finer. From the end of this he draws out a few fibres from the flax, hemp, &c., and, having dipped his fingers in water, wets the fibres and rubs them together, which, by the glutine remaining in them, will cause them to adhere and produce a fine and uniform appearance of thread, which may be spun upon machinery.

When the flax is intended to be bleached before it is spun, Mr Bundy has a patent contrivance for the acomplishment of that purpose.

It consists of certain trays or cradles to be moved in the water or other fluid, to be used for the bleaching or whitening of the flax or hemp.

The flax or hemp, after it has been broken and worked in the breaking and rubbing machine, invented by this gentleman, and which has been already described, should be divided into small quantities of about one ounce each, and these should be tied loosely in the middle with a string, and in this state laid in the trays or cradles, and then be soaked in cold soft water for a day or two, when each parcel should be worked separately, while wet, through a machine, precisely similar to the breaking and rubbing machine already described, except only that the rollers should be cylindrical, and made entirely of wood with metal axles, and the teeth, which will be parallel, should be similar in form to those shown in section at F. This operation will loosen the gluten and colouring matter for the rinsing and wringing which must follow. The flax must then be again disposed in a flat and smooth manner, in such trays or cradles, and again be put to soak in sufficient soft water to cover it, in which a small quantity of soap, in the proportion of about seven pounds of soap, to each hundred-weight of flax, has been previously dissolved, and in this state it should remain for two or three days longer, and then be again worked through the machine, and rinsed with clear water and wrung, which will render it sufficiently clean and white for most purposes. But if it be required to be still softer, for spinning into yarn of the finest quality, it must be boiled in a very large quantity of soft water, with the same or a larger proportion of soap, for half an hour or more, and then be rinsed, after which it must be carefully and thoroughly dried. When it is quite dry, it should be worked through the breaking machine before described, with conical rollers, to open it sufficiently for hackling or dressing.

The wooden trays or cradles should be shallow, each being about one inch in depth, and of sufficient length to hold the materials; they must have open lath bottoms, and a single course or layer of the flax, tied in parcels as aforesaid, occupies one tray; other trays of the same description are to be piled or placed upon this, and so on to any convenient number of trays, until the soaking-tubs or boilers are sufficiently filled. These trays must be tied, or otherwise attached together, and are to be moved quickly up and down in the water, either by hand or by machinery. By their construction, it is evident that the water will have access to every part of the flax, which will have room to rise and swell, without any danger of entanglement, while, by the motion, the cleansing process will be much more effectually carried on than it has hitherto been by simply washing, soaking, or boiling, without it.

It is almost needless to observe, that the trays and soaking vessels must be composed of such wood or materials as will not stain the flax; and that the height and dimensions of the breaking-machine must be suited to the person working it. In fig. Q, the conical rollers are drawn one-third of the size which the patentee found most convenient; viz. seven inches long in the working part, three and a half inches diameter at the largest end, and two inches diameter at the smallest end.

The flax, after it has undergone the process of breaking, is ready for the hackle, which is an instrument or tool constructed for the purpose of hackling or straightening the fibres of the flax. It is represented by figs. 448 and 449.

It is a square flat piece of wood, as seen at A and B. When used, it is firmly fixed to a bench before the workman, who strikes the flax upon the teeth of the hackle, and draws it quickly through the teeth. To persons unacquainted with this kind of work, this may seem a very simple operation; but in fact it requires as much practice to acquire the method of hackling well, and without wasting the flax, as any other operation in the whole manufacture of linen. The workmen use fine, or coarser and wider teethed hackles, according to the quality of the flax; generally putting the flax through two hackles, a coarser one at first, and then a finer one in finishing it.

About the year 1787, Messrs Kendrew and Porthouse, of Darlington, obtained a patent for spinning a flaxen thread by means of machinery; prior to that time, we believe, the rock and wheel, variously modified, occasionally for superior spinners to form two threads at once, were universally employed. In Ireland especially, even at the present day, this method is much practised. The flax, rendered straight and smooth by hackling, is wrapped closely round the rock, from which it is gradually drawn by the left hand, whilst the thumb and fore-finger of the right, moistened with water, are employed in adjusting the fibres, and directing the thread. A bobbin and flyer, placed upon a horizontal spindle, serve to give the twist, and to take up the finished thread; their motion is derived from a wheel, impelled by the foot through a treadle and crank, by means of an endless-band passing round a pulley of much smaller diameter, which is fixed upon the spindle.

The straightness and smoothness of the fibres of flax, so different from the corrugation and adhesiveness of cotton and wool, with their extraordinary length, seemed to demand an arrangement in machine-spinning very different from what has been already delineated.

In the patent alluded to, the hackled flax was extended upon a horizontal frame, at fig. 410*, to be carried between the rollers B *b*, and afterwards to pass along with the cylinder C, (revolving with a velocity equal to that of any point of the circumference of B,) under several successive rollers, until it arrived at the drawing-rollers D *d*; the twist and removal of the thread then taking place by the flyer and bobbin, as before described. The rollers E, F, G, H, I, if of equal weights, will, on account of their respective positions, press with unequal force; the one resting upon the vertex of the cylinder being evidently the most efficacious, and with the surface beneath acting probably the part of a pair of holding-rollers to fibres of the length of nearly one-fourth of the circumference; whilst for fibres which are longer or shorter, the other rollers, according to their place, will answer the same purpose. In this, however, there is no new principle; and although modified, it amounts merely to the operation of holding and drawing rollers. From some impediments thrown in the way of the Scotch flax-spinners by the patentees before mentioned, they began, we believe, in no long time, to place their rollers in a straight line, at distances suitable to the length of the fibres. Of the excellence of this arrangement a working model made for the Andersonian Institution in Glasgow, in the year 1803, afforded sufficient evidence.

WEAVING.

In the preceding articles, cotton, wool, silk, and flax, we have traced the process of forming the four commonest fibrous materials to the state of thread or yarn, and now purpose, in general terms, to treat of their further destination in the formation of the various superficial structures termed web or cloth.

The structures which come under the name of cloth are formed of two distinct layers of yarns, generally crossing each other at right angles, termed the warp, and the woof or weft; and as all cloths, however varied, are constructed of these two distinct portions of threads, the mind will, when made to comprehend the mode and form of loom used in the weaving of one material, be able easily to conceive its application to other sorts, varying only in dimensions and strength, according as the weight of the yarn or size of the cloth may demand.

Prior to commencing the weaving of any material, it is necessary to prepare the yarn for the loom, one process of which preparation is, in fact, the measuring and arranging the threads that are to compose the warp in a parallel direction, termed *warping*.

The warp, or that layer of threads which extends the length of the piece to be woven, requires the most attention in the preparation. To form a warp, it is necessary to be very particular in the number and quality of the yarns; for upon their fineness, length, and breadth, depend the fineness, length, and breadth, of the piece to be woven. Though this may appear a very simple operation, yet, the performing of it with expedition and accuracy demands some mechanical skill. The machine for effecting this object is termed the warping-mill, and, though considerably larger, may be compared to the reel described in the cotton manufacture: but the spindle upon which it revolves is placed perpendicularly. The reel cannot easily be made of such dimensions that a thread measured upon its circumference shall be equal to the required length of the warp; and consequently the layer of yarns is placed in a direction parallel to the axis of the reel, and wound upon it in a spiral direction till they arrive at the upper end, when the motions of the mill and the yarns are reversed, and a fresh layer is placed upon the same parts of the reel. By this method of plying the layers of yarn, it is obvious that a small number of ends may be doubled so as to form the required breadth of the warp. If the twist is spun on cops, it must, prior to warping, be wound on bobbins, which bobbins are placed in a frame to be wound off upon the warping-mill.

The next operation to be effected in the manufacture of cotton goods is that of dressing the warp; that is, impregnating it with certain gummy or gelatinous matter, and coating the surface of the yarns, to enable the warp to sustain the abrasion to which it is subjected in the process of weaving, as will be seen when that process is described. In preparing the wool and silk yarns for the looms, dressing is in general only required for the finest sort, when a little mucilage of gum arabic, or of jelly made from rabbit or other light skins, is used to increase in a slight degree the tenacity.

As it is of considerable importance in the dressing of warps to have the materials dispersed equally over the surfaces, many ingenious mechanics have constructed machines for that purpose; the general principles of which are the placing of the warp on a roller, and immersing it in the mucilage, which allows it to be drawn off covered with mucilaginous matter. The superfluous mucilage is brushed off, and the yarn is put in a frame, and by means of revolving fans is dried and rendered fit to be put in the loom. In cases where the manufacturer operates separately, the weaver dresses the warp, by extending and carefully brushing it over with paste, and drying it in the air, prior to placing it in the loom.

Before we proceed to give a description of the looms used in the manufacture of cloth, it is requisite that the reader should be acquainted with the various sorts of structure arising from the different dispositions of the warp and weft, termed fabric.

The simplest mode of disposing of the warp and weft is called common fabric; and taking into account the quantity of yarn used for a given superficies of cloth, is certainly, so far as respects its strength and durability, the most advantageous mode of distributing it.

Fig. 412 is a section of a piece of cloth wove in the common fabric. The circles represent the warp in section, and the weft is seen passing alternately above and below each succeeding yarn, and the return, or next layer of weft, passing beneath those threads over which it had passed before, and *vice versâ*.

Fig. 413 represents a section of a piece of cloth wove to a twilled pattern. In this the yarn of the weft passes alternately over four and under one of the threads of the warp, and *vice versâ* in its return.

Fig. 414 represents the section of a dimity or kerseymere, in which the weft passes over four and under four, then over one and under four, and over four and under one, which places it in a position to begin again; when the passage of the weft, as it regards the warp, is exactly reversed.

Fig. 415 shows the construction of a double cloth woven with two warps. This mode of weaving is mostly applied to the construction of carpets, and the transposition of the colours in the pattern arises from it. All the divers modes of passing the weft among the warp may be introduced in this figure, and whatever is effected with one web of warp is alternately effected with the other, as may be seen by the figure. It is therefore easy to conceive, that all the various patterns in woven goods are obtained by differently disposing of the warp, that is, lifting a greater or smaller quantity of it at a time, which places the weft on either surface of the cloth at pleasure.

The common loom, or that which is destined to weave cloth of the common fabric, is the most simple in its construction, as the mode of lifting and depressing the portions of the warp are similar at each throw of the shuttle. A top view of a loom of this description is given in fig. 416.

A is a warp.

B a roller upon which the warp is wound, called the yarn-beam, and applied to maintain the warp in a stretched position by means of a lever passing through one of its ends and tightened with a string; as will be more clearly understood by referring to the perpendicular section at No. 2 of this figure.

C C C are rods placed between the threads of the warp to keep them separate, so that they may pass forward clear of each other, when the warp is fed forward and filled with the weft, these rods are at different periods moved towards the warp-roller B.

At D are the heald or heddles, formed of two rods, one above and the other below the piece, and connected together by numerous strings, through which distinct portions of the warp pass, and by means of the treadles below are lifted and depressed. A detached view of two leaves of a heddle is represented in section in fig. 417.

a a, a^1 a^1, are the top and bottom bars, and the two lines a^2 a^2 represent two adjacent yarns of the warp, so that when a a rises it carries with it one thread, while the other thread which is passed through the lower loop of this heddle is depressed by the other heddles. The next part, E, fig. 416, is a frame to carry the reed, called the lay. A portion of the reed is shown detached in fig. 418. It is, except when used in cloth of the coarsest description, formed of flatted wires, placed parallel to each other, and governed, as to their thickness and adjacency, by the fineness of the fabric in which they are to be used.

The lay, fig. 416, which carries the reed, is hung from a bar capable of vibrating on gudgeons in the upper frame of the loom. The two thin elastic pieces of wood which suspend the lay are called swords, and may be seen at F 1, F 1, fig. 419. The reed thus hung is just beyond the line of the shuttle-flight, and has one or two threads of the warp passed between each of its wires, which wires are termed dents. Its use is to strike home the thread of the weft immediately after it has been delivered by the flight of the shuttle; it is therefore pushed by the weaver towards the yarn-beam, prior to each flight of the shuttle, and when the weft has been delivered, it is allowed to return and strike home that individual thread.

The next part of the loom is the shuttle-boxes, which are placed at F, F. In weaving narrow goods, the shuttle is passed between the warp by the hands of the weaver, but when the cloth is fine, or of a breadth to preclude this mode, the fly-shuttle, which is much more compact, and has a spindle to carry a cop upon it, is introduced. This form of shuttle is represented in fig. 420. The shuttle with its cop is placed in the shuttle box, which is of dimensions just sufficient to receive it. In fig. 419 is represented the reed and lay at F^2 F^2. The shuttle is driven to the opposite boxes by means of a small piece of wood, called a driver, which lies behind the shuttle in each box, and is capable of being swiftly drawn forward by a string attached to it, and connected with a handle, G. The weaver holds the handle in his hand, and by a jerk throws the shuttle across the web into the opposite box, and then, by bringing the lay towards him, strikes home the weft. The flight of the shuttle requires adjustment or skill, as its impetus must be proportioned to the weight of the yarn which it carries, and the freedom with which the cop unwinds.

If two or three colours of weft are to be put into a piece, so as to form a pattern, there are two or three shuttles to be thrown; in such case, the shuttle-boxes are formed in three parts, as represented by the dotted lines. This combination of shuttle-boxes is capable of being moved upwards and downwards upon the lay by the small levers, H, H, fixed upon the swords, and worked by the handle I, so that the shuttle to be thrown may be brought opposite to the division in the warp through which it is to fly.

As the cloth is perfected, it is led over the breast-beam K, fig. 416, and is, by means of a ratchet-wheel, wound upon the roller L, which is termed the cloth-beam. At *m* is a stretching-rod, formed of two pieces, and lashed with a piece of band, in such manner, that the ends are forced outwards, as may be seen in the figure. This rod has small points at each end, which pass through the selvage of the cloth, and serve to keep the cloth stretched, as otherwise the action of the weft would occasion it to pucker and lay in hollows. The weaver sits behind the breast-beam, and in fine work, where the breast-beam is dispensed with, behind the cloth-roller.

Such is the construction of loom used in plain-weaving; and by examining it attentively, it will be seen that by an additional number of heddles any required movements of the warp can be effected, and by varieties of weft other diversifications attained almost to infinity. The greatest skill required in the act of weaving by hand is the directing of the flight of the shuttle, where the impetus given should just suffice to deliver it in the opposite box. The striking home of the weft should be done with a regular force, and the preparatory operations carefully attended to, that the warp may wind off freely and regularly with an equal tension in all its parts.

From an examination of the movements of so simple a machine as the loom, the machinist will instantly conceive the practicability of applying power to produce the necessary movements; we shall, therefore, present the reader with two combinations of this class which are called power-looms: the first invented by a Mr Millar.

Fig. 421 represents a section of a power-loom, in which all the operations are effected by means of treadles, moved by wipers or eccentrics.

A, the main shaft, to which the power is communicated, carrying the wipers, one of which is seen at A. A 1, the yarn-beam; B, three rollers, on the lower of which the cloth is wound after passing above and between the two upper ones; C, C, the heddles; D, D, the treadles, to which the heddles are attached by means of a line passing over a pulley, in such manner, that the depression of one heddle occasions the raising of the other; E, E, the lay carrying the reed; the motion is given to the lay by a wiper moving a treadle that is attached to the lay by means of the line and crank at F. The return motion for striking home the weft is given by a weight hanging over a pulley, as may be seen in the figure. The flight of the shuttle is occasioned by attaching the strings from the drivers to another treadle, which treadle is worked at the proper periods by another wiper.

Another form of power-loom, called the crank-loom, is used, and varies from the preceding in the mode by which the movement is given to the heddles. In this construction of loom the revolving shaft is placed immediately under the heddles, which are suspended over a pulley similarly to the loom last described; but the motion is given to them by means of their being attached to two opposite cranks on the shaft. The motion is given to the lay by a crank upon another shaft, which is made to revolve twice, while the shaft that moves the heddles revolves once. By this, it is evident, that the warp is opened, and the shuttle thrown twice, during one revolution of the first shaft.

The flight is given to the shuttle by the cords of the drivers being attached to an upright lever, as represented in fig. 422.

The cords, *c*, *c*, of the drivers are attached to the lever, *e*, which, by means of the arms, *h*, *i*, is caused to vibrate in opposite directions upon the centre, *g*, being alternately struck, by two projecting pieces upon the first mentioned crank-shaft, which causes the lever, *e*, to vibrate in a plane parallel to the crank-shafts, and gives flight to the shuttle, at the period when the warp is opened.

In either of these plans for working looms by power, if the number of heddles is required to be increased, in order to produce any figure, it is easily effected, by varying the number and the position of the cranks or wipers.

But, though great variations in the movements of a warp may be effected by using many heddles, yet when the number of heddles and the number of cranks are increased, great objections arise to their being used; consequently, another construction of loom, called the draw-loom, is introduced when complicated figures are to be woven. In this loom the changes are effected by raising one portion of the warp entirely out of the way, while the other is wrought by the heddles at the time it is being filled with the weft; the part raised is then lowered into work, and other yarns of the warp lifted out of the way.

A loom on this principle is shown in fig. 423. For weaving carpets by this method, every yarn of the warp has a line attached to it, which lines are brought together in one connected piece, according to the portion of warp to be raised at once, and carried over the pulleys as at A, and attached to the fixed beam at B. This portion is called the tail. Below the warp these lines, which are called the simples, are kept in a state of tension by weights, as at C; and in order to keep them distinctly apart, are made to pass through a board perforated with holes at D. Other lines are attached to the tail, capable of being pulled by handles, as at E, by which means such portions of the warp as are required can be raised. By this contrivance the greatest intricacy of pattern can be attained; but the attaching of the simples to the different parts of the warp, by means of small eyes of metal through which the threads of the warp are made to pass, is a work of considerable labour. Damask table-cloths are produced by this loom.

It would occupy too much room were we to enter with more exactness into the great variety of looms which ingenuity has constructed; what we have said therefore we trust will be sufficient to convey to the reader a perfect knowledge of the principles of forming those various fabrics which are termed cloth. In the weaving of ribands and other ornamental works, many extraneous substances, totally unconnected with the warp or weft, are thrown in, which affords the designers an additional scope for the display of embellishments. These substances are merely held in the fabric by the intersection of the two staple parts, the warp and the weft, and are by the weavers denominated whips.

In the formation of cloth from the yarn of cotton, silk, hemp, and long wool, denominated worsted, the fabric when taken from the loom is, so far as it regards the weaving, in a perfect state; the further operations, both mechanical and chemical, which it undergoes, may properly be considered as tending merely to its further embellishment. These operations consist generally of singing the superfluous fibres from the surface of the cloth, by drawing it over hot irons, and after bleaching or dying, submitting the cotton and linen goods to pressure between heavy iron cylinders, for the purpose of giving it a gloss, and the worsted, called camblets or stuffs, between warm copper-plates, called hot-pressing, to give it a smooth and finished appearance.

In the formation of cloth from short wool, of which our wearing apparel is made, the loom cannot be said similarly to have completed the operation. In this branch of manufacture, the yarn is woven in a common loom in the manner we have shown, and called common fabric, but when the piece is taken from the loom the web is too loose and open, and is consequently submitted to another operation, called fulling, or milling. The cloth, after it is, by repeated washings, divested of the oil that was put in it in the act of carding the wool, is taken to the fulling-mill, where it is wet with soap and water, and subjected to repeated compressions by the action of a large beater formed of wood, called a stock, which repeatedly changes the position of the cloth, and by its continuous action causes the fibres to felt and combine more closely together, so that the stability of the texture is greatly improved.

The cloth then undergoes the operation of the gig-mill, which is formed of a cylinder, somewhat similar to that of a carding-engine, covered with the heads or burs of a large species of thistle, called teasels. The cloth is strained on this engine, and by continued running up and down, the fibres or nap is raised and laid in a parallel direction: it is then cut close by shears, and afterwards submitted to the dyer, if so destined; but in many colours, for the best cloths, this process is effected in the wool, prior to the commencement of the manufacture.

It is afterwards scoured, and again submitted to the gig-mill for raising, again cut by the shears, and then pressed for the market.

In trying the strength of cloth, it should always stand both in the direction of the warp and the weft; and the substance of which all parts are formed should be known by separate examination, and not by mere superficial inspection, as the surface may easily be formed to hide defects, and display apparent value.

ROPE-MAKING.

In rendering the hemp-plant proper for the uses of the rope-maker, it has to undergo a variety of processes.

The first of these is *retting*, that is, exposing it to the action of the dew, or water; the former termed *dew-retting;* the latter, by which the finest hemp is produced, *water-retting*. In both or either of these processes, the quality of the hemp is said to be influenced by the state of the weather, and the finest to be produced when showers have mostly prevailed.

In *dew-retting*, the hemp-stalks, immediately after being pulled, are spread out, in a thin, even, and regular way, so as to keep exact rows, on a fine level piece of close old sward land, for the space of three, six, and sometimes eight weeks, as circumstances may require; during which, they are turned two or three times in the week, according to the state of the atmosphere.

The motive for thus spreading it out upon the ground is, that the dew, by penetrating into the plant, may render the separation of the rind from the stem or bur easy to be accomplished. When the dew has acted upon it sufficiently for this purpose, it is tied up into large bundles, and carried home and slacked, or otherwise it is put into a covered building, till wanted to be formed into hemp.

This process, called *grassing*, requires great nicety and attention, that the texture of the hemp may not be injured either by too long continuance on the sward, or by being removed before the hempy substance is rendered sufficiently separable.

In *water-retting*, the much more common and speedy method is, to tie the hemp-plant into small bundles, by means of bands at each end,* and in general to deposit it bundle upon bundle, in a direct and crossing manner, in a pond of standing water, to form what is called a bed of hemp. This bed, when formed of as great a thickness as the depth of the water will admit, which some think can hardly be too great, though five or six feet are the usual depths, is loaded with large pieces of heavy wood until the whole is immersed in the water. In choosing ponds, those should be preferred that have clayey bottoms.

When the hemp-plant has remained in the water for about five or six days, varied according to the nature of the pond and the state of the weather, it is taken out, and conveyed to a piece of mown grass or other sward land, which is free from all sorts of animals. Here the bundles are untied, and the hemp-stalks spread out thin, stem by stem. While in this state, especially in moist weather, they must be carefully turned every second day, to prevent their being injured by the worm casts. In this way they are kept for about five or six weeks, when they are gathered up, tied in large bundles, and kept perfectly dry in a house or small stack, till wanted for use.

In some of the northern parts of Scotland, the hemp, after it has been pulled, and cleared of its leaves, seeds, and branches, by means of a ripple, is formed into bundles of twelve handfuls each, and steeped in a manner similar to flax, till its reed becomes capable of parting from the bark. In this process, it is favourable to give it rather too much than too little of time; and let it be observed, that the most slender hemp requires the greatest length of time in the water. Where the quantity of hemp is only small, the hempy part may be separated from the reed by hand-labour; but where it is large, drying and breaking it in the manner of flax is strongly recommended.

After the hemp has been taken out of the water, it is not spread out upon the grass-ground in the way of flax, but set up in an inclined position against cords arranged for the purpose, or by any other method by which it can receive the full benefit of the air till it be perfectly dried, which may be known by its rising in blisters from the boon. As soon as it has been reeded, it must be divested of the mucilaginous material which it contains, by pouring water upon and repeatedly squeezing it. In this part of the process great care must be taken to prevent the fibres from getting entangled, as by that means great waste will be incurred.

M. Brealle, on the Continent, has suggested a mode, very different to any of these, for the purpose of steeping hemp, the advantages of which, it is asserted, have been fully proved by numerous trials. The process consists in heating water in a vessel, or vat, to the temperature of from 72 to 75 degrees of Reaumer, and dissolving in it a quantity of green soap, in the proportion of 1 to 48 of the hemp: the body of the water being about forty times the weight of the hemp. When this preparation is made, the hemp is thrown into it, and floats on the surface, and the vessel being immediately covered, the fire is put out. In this state the hemp is allowed to remain for two hours, at the expiration of which time it will be found to be fully steeped.

The principal superiority of this method, besides the great saving of time and expense, is said to consist in the hemp affording a greater proportion of tow. The value of the fuel, as well as the time employed in the process, should, however, be well considered in such cases. Besides these, it is said to promote the cultivation of the hemp crops, by the facility which it affords to the preparation, even in such situations as are not contiguous to rivers, streams, or ponds; it also obviates any ill consequences that might possibly ensue from the putrid effluvia of the atmosphere, and the corruption of the waters, induced by it, which last are well known to destroy the fish contained in them, as also to prove hurtful to the cattle that drink of them.

In consequence of the great trouble and expense attendant upon the process of water-retting, the hemp is frequently left for seed; in which case, it is commonly stacked up and well covered for the winter season, in order that it may be thinly spread out in about January or the following month. Where this can be executed during the period of a snow, the hemp comes much more readily to a good colour, and forms strong coarse cloths; but it is far inferior to that pulled in due season, and which has undergone the water-retting operation.

Various contrivances have been made in the form of ponds and pits, for the steeping of hemp; but the one which seems to possess the most merit is described in the Norfolk Report, as the invention of Mr Rainbeard; by using of which, the hemp can be deposited in the pit, without the necessity of any person getting wet. The pond is an old marl-pit, with a regular slope from one side, where the hemp is prepared, to the depth of eight feet on the other side. On the slope, above the water, the hemp is built into a square stack upon a frame of timber, of such a height as will float and bear a man without wetting his feet: this is slid down upon the frame into the water, and a person on the opposite bank draws it to the spot where it is to be sunk. Mr Rainbeard has found by experience, that the hemp does soonest at the bottom, and would not object to 16 feet of water. By means of this very useful contrivance he can put in a wagon-load in an hour. The sheaves are taken out one by one in the usual way; but it is suggested, that some more expeditious and simple contrivance, either upon the principle of the lever, or some other, should be resorted to for effecting the desired purpose.

In preparing the hemp for the hackle, the work is executed chiefly by the beetle, first using a coarse, and then a finer brake: it may, however, be more expeditiously performed by the rollers of a lint-mill. In either mode, shaking the handfuls frequently with force is necessary. In cases where the plant has not been sufficiently watered to loosen the rind, the operation of peeling must be performed by the hand.

Another method for effecting this purpose is the hemp-mill, which is much used in America. It consists simply of a large heavy stone in the form of a sugar-loaf, having the small end cut off. Thus shaped, it readily moves round in a circle, when passing upon a plane. The motion is given by the impulse of water on a wheel, and the hemp, deposited on the receiving floor of the mill, is, by the weight and revolutions of the stone, perfectly crushed and broken.

Still, however, the fluted rollers of a lint-mill are the best means of performing the work, provided sufficient care be taken to guard against accidents.

When the hemp has been completely broken, it is submitted to another operation, called swingling, or scotching; the intention of which is, to separate the reed from the hemp. This operation is sometimes performed by a labourer, who takes a handful of hemp in his left hand, and while holding it over the sharp edge of a board, strikes it with the fine edge of a long flat straight piece of wood, usually termed a swingle-hand or scotcher; but this way is both laborious and tedious; consequently, mills moved by water, having a number of scotchers fixed upon the same axle-tree, and moving with great velocity, are much more frequently used. The work, in this case, is executed with much greater expedition, and far less fatigue of the workmen; but the velocity of the mill occasions a great waste of hemp.

Before the hemp prepared in this manner is subjected to the hackle, it mostly undergoes another process, termed beetling; by which the fibres of the hemp become more loosened and divided. The beetles employed with this intention are moved by the power either of the hand or water, which may be considered best.

The implements used in preparing hemp for the operation of spinning are so very similar to those described in the preparatory processes of the flax-manufacture, that we do not consider it necessary to give more than a general description of the processes; we shall therefore conclude this article with an accurate description of a patent, taken out by Mr George Duncan, of Liverpool, in March 1813, for his improvements in the different stages of rope-making, and for certain machines adapted for the same.

The first part of the process which he has described, is that for *spinning the yarn for all kinds of cordage, lines, and twine.*

In this part of the invention there are two railways, adjoining and parallel with each other, fixed along the spinning-ground or rope-walk, from one end of it to the other. Upon each of these railways a machine for spinning the yarn is made to travel alternately backwards and forwards, one setting off from the bottom of the ground at the same time that the other sets off from the top, and as they both travel at the same rate, the former arrives at the top of the ground at the same time the latter arrives at the bottom.

These spinning-machines are in every respect similar to each other, and are respectively furnished with two sets of twisting spindles; one set being placed at one end of the machine, with the hooks facing the top of the spinning-ground; the other at the opposite end, with the hooks facing the bottom. The spinners employed in spinning with them are, accordingly, divided into two companies, and arranged similar to the machines; the one company at the top, the other at the bottom, of the ground. The number of spindles in each set of each machine should be equal, and also equal with, or rather not fewer than, the number of spinners in each company; or, in other words, as there are in each machine two equal sets of spindles, (four sets in all,) the number of separate spindles in the two machines should not be fewer than double the whole number of spinners employed; because one set only in each machine is occupied at the same time in spinning, the other set being in the mean time engaged in retaining the yarns last spun from it, and following them back to the winding-machine.

The manner in which the operation is performed is as follows:—The spinning-machines are placed, as before described, one at each end of the spinning-ground, on its respective railway, ready to set off. Each spinner of the two companies immediately attaches his hemp or flax to the spindle of the machine that is nearest to him; and the motions of both machines, excepting those of that set of twisting-spindles facing the opposite company, are then struck into geer, and each machine recedes from its own company, spinning and leaving the yarn on separate guides or hooks as it proceeds onwards, the one down and the other up the ground, the one arriving and striking itself out of motion at the bottom, when the other arrives and strikes itself out of motion at the top. Each spinner of the two companies then detaches the yarn in his hand from the hemp or flax which he was spinning, and fixes the end of the piece that is spun to a winding-up reel, in a machine stationed behind or near him, while the other end still remains attached to the spindle-hook of the machine on which it was spun, and which is now at the further end of the ground.

The machines have now changed their company; that is, the machine which formerly belonged to the company at the top, now belongs to the company at the bottom; and that which belonged to the company at the bottom, belongs now to the company at the top. Each spinner, therefore, of both companies, immediately attaches his hemp or flax to the spindles left vacant by the opposite company, and the motions of the spindles to which the hemp or flax is attached being struck into geer, the spinning proceeds as before; during which, the respective winding-machines wind up the yarns last spun, regularly as the spinning-machine, to whose spindles they are attached, and which have remained stationary, advances towards it from the other end.

The spinning of the two sets of yarn, and winding up of the two last spun, being finished at one and the same time, the whole machinery again stops, and each spinner, as before, immediately detaches the yarn in his hand from the hemp or flax, and then detaches from one of the spindle-hooks of the spinning-machine just arrived, the yarn which he had on the former occasion spun, and which has just been wound up on one of the reels of the winding-machine, as closely as the short length necessarily intervening between the spinning and winding-machines will allow. The two ends of these yarns he splices together, so that the yarn just spun, lying on the guides or hooks along the whole length of the spinning-ground, is now ready to be wound up. The spinners then attach their hemp to the emptied hooks, the machines are again struck into motion, the spinning and winding go on as before, and the same procedure continues to be renewed each time.

The general principle which constitutes this mode of operation, and consequent facilities of the invention, are, that one set of spindles in each machine is always employed in spinning, while the yarns spun by and attached to the hooks of the other set at the opposite end of the machine are winding up, so that every spinner is constantly kept at work in spinning, excepting the short interval when splicing the yarn, and preparing to set on to spin. Throughout the whole of the operation, therefore, whatever one of the spinning and the winding machines may be performing, and one of the company of spinners employed in doing, the other spinning and winding machines, and company of spinners, are, in every respect, similarly engaged.

An endless rope, driven by an external machinery, gives the travelling and twisting motions to both spinning-machines; and the whole of these motions are connected with and bear a given proportion to each other, capable of being regulated to suit the speed required. The two winding-machines may also be driven by the endless rope. All or any of these machines may, nevertheless, be driven by distinct endless ropes, or by any other method or methods in use for driving locomotive machinery, provided the proportionate speed be kept up.

The application of the rack, hereafter described, will be the most accurate for regulating the travelling-movement of the spinning or any other machine, on a rope walk; but as the resistance in the present case is very trifling, the motion given to the truck-wheels of the spinning-machine, as shown in the engravings, will answer the purpose at less expense.

As a further improvement, Mr Duncan invented an additional apparatus for giving an after-twist, which either may or may not be adopted. The object of this improvement is, to prevent the yarns losing strength, which otherwise they do, by losing twist by the counter-twist of the strand, and other subsequent operations. This is effected in a simple and convenient way, by continuing the twisting for a sufficient length of time after the travelling motion of the spinning-machine has ceased; by which means, an additional twist is given to the yarns after they are spun to their full length; and this is done while the spinners are splicing them at the other end of the spinning-ground, and preparing again to set on to spin, without occupying any of their time for the purpose. The effect of this part of the invention for the after-twist has been produced in different ways by others; but by modes either so complicated or expensive, as not to be conveniently available in practice.

The principal advantages to be derived from this method of spinning are the following:

First. The spinners are enabled, at much less expense, to spin a greater quantity of hand-spun yarn than they can by any other method in the same space of time; because, except while splicing the threads, they are constantly occupied in spinning; and have neither to hook up the threads, nor to travel up and down the walk, so that their time and attention is solely confined to the delivering of the hemp or flax from their hands. Secondly. The speed of the spinning-machine, besides being uniform, is proportioned to the full extent of work the spinners can conveniently accomplish, which, in some measure, compels them to produce the greatest possible quantity; and as the machine is constructed so as to lift the threads off the hooks, and follow them up to the winding-machine, little or no attendance is required from wheel-boys or followers. Thirdly. The spinners are enabled, partly from their whole skill and attention being confined to the one object, of simply delivering the hemp or flax from their fingers, and partly from the requisite degree of twist being given by machinery, to produce a superior quality of yarn.

And fourthly. The hemp to be spun by this machinery may either be dressed in the usual way, or prepared and dressed on the hackling-machines, which draw out the whole in a long sliver; and in either case it may be spun from the end of the fibres, by which means the strongest yarn is formed. It may, however, be spun from the spinner's waist, and with more convenience than in the common way, because, by this method, the spinners remain always in a room at each end of the spinning-ground; consequently, the hemp is not so liable to be discomposed as when they have to travel up and down its whole length; neither, for the same reason, is it so liable to be wasted.

The expense attendant upon erecting the spinning machinery, with all its connexions, and the power requisite to drive it, is comparatively trifling. In making the spinning machinery, various forms or shapes may be adopted, as they may be made to travel on railways on the ground, or on railways suspended from the beams of the rope-walk, or fixed upon or above them, as may be thought proper; and the disposition of the necessary machinery may be arranged and diversified to suit the situations of the railways, and the construction and conveniences of the rope-walk.

The mode shown in figs. 469, 470 and 471, is most preferred by Mr Duncan, merely because it occupies least room in proportion to the number of spindles the spinning machines can employ. The whole width of a rope-walk, required by this mode, need not be more than six feet, except at each end, where, of course, sufficient width convenient for the spinners, and for the winding-machine and dressed hemp, must be allowed. In this narrow space no less than twenty-four threads may be constantly kept spinning at one time, and as many winding up; so that besides every other advantage, the saving in the original cost of a spinning-ground on this plan, and in the expense of covering it in, will be considerable.

In the explanations to the figs. 478 and 479, is shown how other arrangements may be made by which the competent mechanic will be enabled to adapt or diversify the form of the machines, and form and disposition of the machinery, to suit any situation in a ropery which is most convenient, or of little use for other purposes.

In that part of the drawing, entitled "Rope-spinning," from A to B is supposed to be the spinning-ground, shown as broken off in the middle, for want of room to show it in full length; C C and C C, on each side of the break, is one railway; D D and D D the other.

Fig. 469 is a plan of one of the spinning-machines, at the top of the ground, on the railway C C.

Fig. 470 is the other, exactly of the same construction, at the bottom of the ground; on the railway D D; and

Fig. 471 is a side elevation.

Though both machines are precisely similar, yet some parts of the machinery are omitted in some of the figures, that other parts may be seen more distinctly, and in none of the figures are the whole shown together.

Fig. 473. p 43

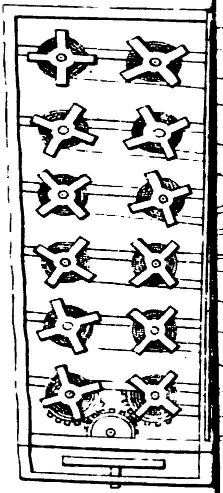


Fig. 472. p 434

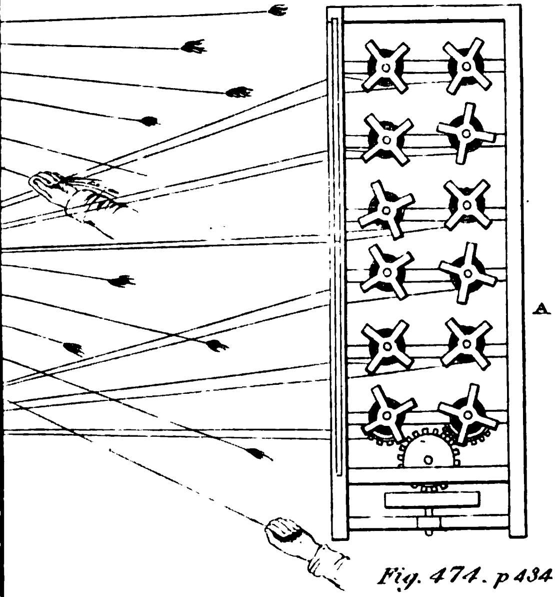
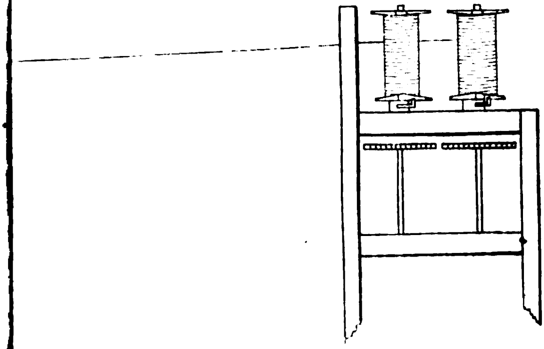


Fig. 474. p 434



E, wherever it occurs, shows the endless rope which drives both machines, and so the rollers or pullies suspended from the beams L over head, which guide and carry it.

The same characters, in all the above figures, wherever they may be used, denote the same part.

F shows the framing of the machines.

a and *b* two grooved sheeves, fastened upon the two upright shafts *c* and *d*, (as best seen in fig. 471,) driven contrary ways by means of the endless rope.

The manner in which the rope goes round, and grasps the sheeves, and occasions their contrary motion, is best seen in fig. 470.

In fig. 471, *e* and *f* are two spur-wheels, fixed upon the shaft *c* and *d*, with a view to equalize their motion.

The twisting motions for each set of spindles are driven by their respective shafts, which, at the same time, drive all the travelling motions. But the twisting motions for one end only are driven at a time; for while the shaft that is nearest to the end from which the spinners are spinning, is driving the twisting motions of that set of spindles, together with all the travelling motions, the shaft nearest to the other end is not driving any, though both shafts are then revolving.

g and *h* in the travelling motions are two pinions, upon loose rounds, alternately driving the wheel *i*, which is fast upon the short upright shaft *k*, and shown only in fig. 471. On the lower end of this shaft is the bevel-wheel *l*, driving, by means of another bevel-wheel, *m*, the cross shaft *n*, upon one end of which are fastened the sheeves 1, 2, 3, and upon the other the sheeves 4, 5, 6, seen best in fig. 469. These sheeves are of different sizes, and one only at each end of the shaft is in use at a time; *o* and *p* are the two axles of the truck-wheels, having the sheeves 7, 8, 9, fastened upon *o*, and upon *p* the sheeves 10, 11, 12. The four truck-wheels *q* are also fastened upon the shafts *o* and *p*, and motion is given to them by two belts; one driven from any one of the sheeves 1, 2, 3, and the other from any one of the sheeves 4, 5, 6, each belt running upon its corresponding sheeve on the axles of the truck-wheel. The turning round of these axles impels, according to the motion given to them, the machine forward; which motion can, by the sheeves being of different sizes, be regulated as occasion may require.

On the lower end of the shafts *c* and *d* of the twisting motions are the sheeves *r* and *s*, on loose rounds, each in its turn carried about by catch-boxes, (as shall be hereafter explained,) and driving the upright rollers or cylinders G and H, by means of belts going round the sheeves *t* and *v*, fastened on the axles of the rollers. These rollers give motion to the twisting spindles by separate bands or belts passing round a whirl on each spindle; in each machine are placed twenty-four spindles, twelve at each end, or six at each corner of each end, the positions of which are seen in figs. 469 and 470. In either of these figures, one spindle at each of the four corners only appears, the other five being ranged in a direct line underneath; but the manner in which they range is seen in fig. 471. In fig. 471, twelve, or one-half of the number of spindles, appear on the nearest side; six, or half a set, at each end; the other half appear similarly situated on the opposite side. These two sets are alternately employed, the one in spinning, and the other in holding and following the yarns that are winding up; *z z*, fig. 471, are ratchet-wheels and catches, placed on the axles of the rollers G and H, to keep the yarns from untwisting when winding up.

Figs. 469 and 470 best show the carriers, projecting from the frame in which the twisting spindles run; the form and use of them, and of the whirls and spindles, are so obvious, that it is not necessary to point them out in any of the figures by a distinguishing character of reference; and, for the same reason, none of the bands or belts are marked.

Having so far described the different motions and appurtenances of the spinning-machine, we shall now proceed more particularly to explain the manner in which they operate.

By an inspection of fig. 471, it will be seen, that the catch of the catch-box 13 is in contact with the catch of the pinion *h*, and the catch of the catch-box 14 with the catch of the sheeves I, and that the catches of the boxes 15 and 16 are not in contact with the corresponding pinion *g* and sheeve *r*.

17 and 18 are two separate levers, one at each end of the machine, alternately used for striking into geer the catches above mentioned; the lever 17 serving for the two boxes 13 and 14, and the lever 18 for the two boxes 15 and 16. 19 and 20 act as swingers or levers from the joints 21 and 22, having claw ends to grasp the catch-boxes 13 and 14; and being coupled with the main lever 17, by means of the connecting rod 23, move them either up or down. When in geer they are held firm by the sneck 24; but on running against a fixture at one end of the spinning-ground, are pulled back, which causes all the motions of the machine to stop. The machine, however, may at any time be stopped, as occasion may require, by pulling back the sneck by hand. The two main levers 17 and 18 are so weighted at the handle end, that when disengaged from their snecks the catch-boxes always fly out of geer. The machine is put in motion by raising the main lever into the sneck by hand. All the machinery on each side of the wheel *i*, at each end of the machine, is precisely alike; the description therefore given of one end may answer for the other. The twisting motions at each end are never in geer at the same time; for those at one end are engaged in spinning one set of threads, while those at the other, whose spindles retain and follow up the other set of threads, (last spun,) to the winding-machine, remain at rest. All the four catch-boxes, 13, 14, 15, and 16, constantly go round with the shafts *c* and *d*, by means of feathers in the shafts acting in grooves in the boxes.

When the catch-box 14 is in contact with the sheeve *s*, it gives motion to the set of twisting-spindles belonging to the roller H, at the same time its accompanying catch-box 13, by being in contact with the pinion *h*, gives a retiring or travelling movement to the whole machine, which is effected by the wheel *i* communicating motion to the four truck-wheels, by the means which have been before described. The wheel *i* is common to both pinions, being turned one way by one pinion, when the machine is retiring from the top of the ground, and the contrary way by the other, when it is retiring from the bottom of the ground; consequently, the cross shaft *n*, which derives its motion from the wheel *i*, turns at the same time both the truck-wheel axles, one way when retiring from the top, and the contrary way when retiring from the bottom; the shaft *n* being common to both truck-wheel axles.

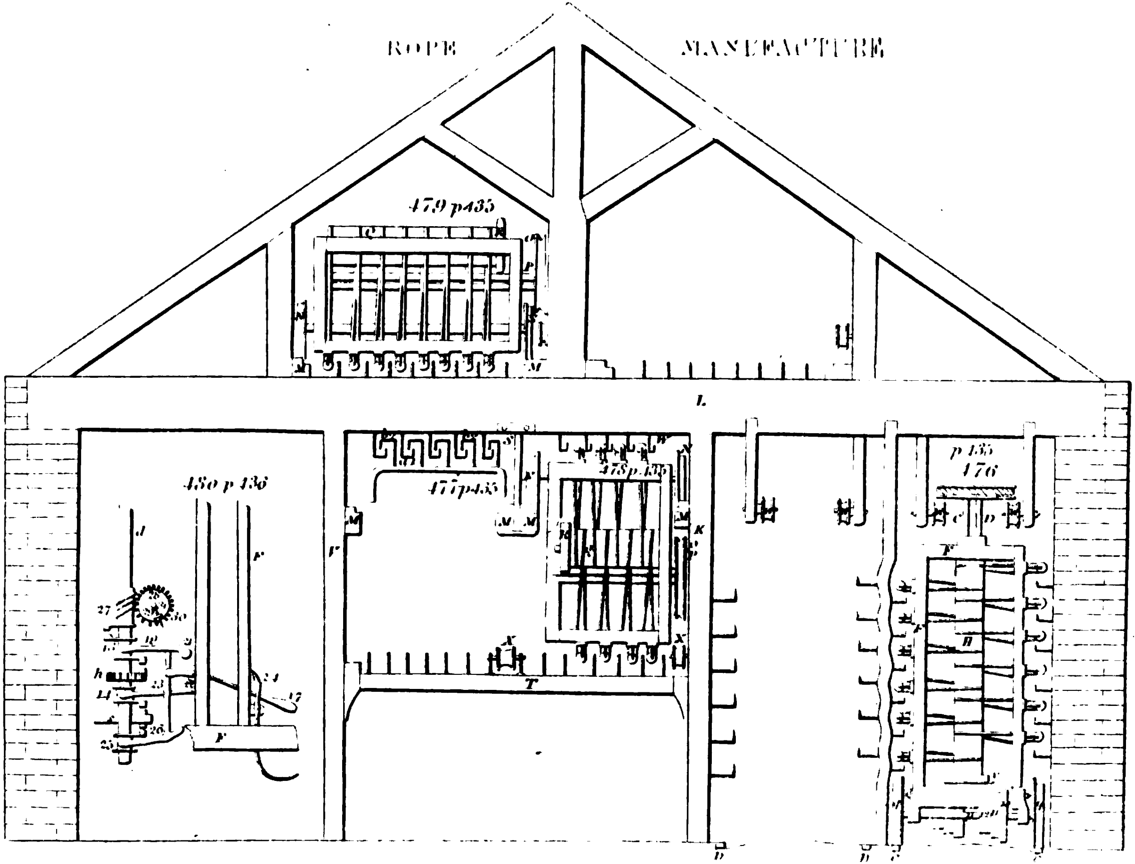
Fig. 472 is the plan of a winding-machine, placed at the top of the spinning-ground, containing twelve reels, corresponding with the number of spindles in each spinning-machine.

Fig. 473 is a plan of a similar winding-machine, placed at the bottom of the ground, containing the same number of reels. Both these winding-machines are mounted so high above the ground as to allow the yarn winding on them to pass over head, that the spinners may have room to move underneath. In the engraving they are placed rather nearer the spinning-machines than they ought to be, from want of room in the plate. When all the spindles of the two spinning-machines are employed, one half in spinning and the other half in following up the yarns to the winding-machine, as has already been described, all the reels of both winding-machines are of course at the same time fully employed in winding up.

Fig. 474, at one end of the ground, shows a side view of the reels, placed

From 175 to 180

ROPE MANUFACTURE



on their spindles, a description of which is unnecessary, as the movements and construction of such machines are well known and understood. In the figure they are represented as only winding one yarn on each reel, in order to explain the improved or patent method of rope-making; but more than one yarn may be wound on any one of these, or any other kind of reel that may be used in my method of spinning, for the convenience of the common method of rope-making, or for other purposes. It is neither convenient, nor necessary, that the endless rope should cease motion, when the spinning-machines have arrived and struck themselves out of geer at the top and bottom of the ground; consequently we will suppose, that the endless rope is in motion, and all the other parts of the machinery at rest, excepting the two shafts *c* and *d*, and their respective catch-boxes. The catch-boxes of each shaft in both machines are in the position of 15 and 16, as seen in fig. 471. Each spinner in the two opposite companies having now attached the hemp to the spindles, nothing remains to be done but to raise by hand the lever 17, fig. 471, (which in the engraving appears to be already done,) and the corresponding lever in the opposite machine; which will cause the spinning and winding to proceed in the manner already described.

When the machines stop, each spinner splices his thread, and throws it on the nearest guide *x*, to keep it out of the way, and to conduct it to the winding-machine. The grooved sheeves *a* and *b*, on the top of the shafts *c* and *d*, to which the endless rope gives the first motion, may be changed when required for sheeves of a larger or smaller diameter, for the purpose of diminishing or increasing all the motions in a proportionate degree. For the same purpose the wheel or sheeve, which gives motion to the endless rope, may also have grooves of different diameters. The sheeves that may be changed for increasing or diminishing the twisting motions, are the four sheeves *t r* for one end of the machine, and *v s* for the other, as seen in fig. 471. In order to obtain more or less travelling motion, the belts may be made to run either on the sheeves 1 and 9, and 6 and 10, or on 2 and 8 and 5 and 11, or on 3 and 7 and 4 and 12, as seen in fig. 469.

Fig. 475, (within which are figs. 476, 477, 478, and 479,) represents an end view of a rope-ground building, set down as eighteen feet wide inside. It is merely divided into portions, to show some different modes of diversifying spinning-machines upon this principle, the different situations in which they may work, and the proportion of room they may occupy according to the number of spindles.

Figs. 478 and 479 show end views of two forms of spinning-machines, different from each other, and from the one already described; but all upon the same principle. The machine in fig. 478 is represented as moving on a railway M M, underneath the beam L, having spindles both above and below. The parts shown in the figure are as follows: N N two of the truck-wheels. O P the endless rope sheeves. Q one of the rollers for turning the spindles. R a sheeve on the end of the roller, answering the same purpose as *t* and *v* in fig. 471. W part of a sheeve on the truck-wheel axle, answering the same purpose as one of those on the axles *o* and *p* in figs. 469 and 470. The carriers, the whirls, the spindles, and their bands, in this machine are the same as in the spinning-machine already described; and their situations are so obvious, as not to require particular characters of reference. Such part of the figure as consists of framing will be obvious. One side of the railway is fixed to the post K; the other side is fixed and rests upon the iron fixture S, hanging from the beam L, which also serves the same purpose for the adjoining railway. X one of the guide pullies for the endless rope. T a rail, (which may occasionally be removed,) laid across, and answering the purpose of both railways, from post V to K, having upright pins at proper distances, for the purpose of bearing and keeping separate the yarns of the lower spindles. The hooks fixed to the under side of the beam L are to answer the same purpose for the yarns of the upper spindles. In order to lay the yarns upon these hooks, a separate guide upon each spindle is fixed upright in a slender rail, fastened to, and projecting two or three feet from, and parallel with, each end of the machine. The shape of these guides is the same as the hooks in the beam, with this exception, that each one has an eye at the point, to convey the yarns in a slanting direction from the spindles, and to lay them upon their respective hooks in the beam when spinning, and also to lift them off when winding up. The manner in which the guides pass between the hooks may be seen in fig. 477, where *a* represents the projecting rail; *b*² the guides, two only of which are marked; it must here be understood, that the spindles are not opposite the eyes of their respective guides, but exactly opposite the upright part of them, and on a level with the eyes. There are many other ways by which the hooking up of the yarns may be effected, but the method just described is conceived to be the most simple. The space between the post V and the iron fixture S, is the room to be occupied by the other spinning-machine.

The spinning-machine, fig. 479, is represented as moving on a railway, laid upon the beam L. It will be seen that this machine is nothing more than the lower part of the one last described, having no spindles on the upper part. The guide pins are in this method driven into the beam. The empty space to the right of this machine is the room to be occupied by its fellow. The letters of reference used in fig. 10, and its appurtenances, apply to the same parts whenever they are used in fig. 479, and its appurtenances. Though these machines, (the end views of which are shown in figs. 478 and 479,) are different from each other in form and arrangement of machinery, and also from the form and arrangement of the one shown in figs. 469, 470, and 471, yet the same principle of the travelling and twisting motions is applicable to all, and therefore it is unnecessary to enter into further explanations respecting them.

Fig. 480 shows the method of giving the after-twist. As the apparatus for this purpose is to be applied to each of the endless rope shafts in each machine, a description of the apparatus as belonging to one of them may be sufficient. This figure is a side view of the apparatus, and is represented as applied to the shaft *d*, in fig. 471; the same characters of reference there used being retained in the present figure, where they denote the same parts. The apparatus for the after-twist is merely an addition, which on the lower part of the figure consists of a catch on the under side of the sheeve *s*, a corresponding catch and catch-box 25, carried round by the shaft, and the lever or swinger 26 to act on the catch-box. The rod 23 is lengthened, to connect this swinger with the other two. On the upper part of the figure is the remainder of the apparatus, consisting of a catch on the upper side of the catch-box 13; the worm on a loose round on the shaft 27, with a catch on the under side, to operate with its corresponding catch on the catch-box 13; the screw-wheel 28 to act in the worm; the arm 29, on a loose round on the axis of the screw-wheel, confined near the circumference of the wheel by the staple 30, but having play the width of the staple, the end of the arm farthest from the axis being intended to act on, and press down, the swinger 19; and the spring 31, fixed on the wheel, which presses against the back of the arm.

The whole of the machinery in the figure is represented out of the geer, and is in the position as when ready to set off from one end of the spinning-ground, to follow the yarns to the winding-machine. In that position it continues until it has arrived at the winding-machine, and the yarns are disengaged from the spindles when the main lever 17 is lifted up by hand into the catch 24, for the purpose of putting the spinning and travelling motions into geer, as formerly described. By the raising up of this lever the swinger 19 is pulled down, and the arm 29 is thus disengaged; which having play within the staple, swings forward by its own weight, clear of the swinger, which is hollowed or bent at that place for the purpose. The object of this is, that the arm may not be in the way of the swinger 19 the next time it goes into gear with the worm. When the machine has returned to the other end of the ground, and the yarns consequently are spun to their full length, the catch 24, on which the main lever rests, is thrown back by the machine going against a fixture in the ground, as has been before mentioned, and the lever, (being sufficiently weighted at the handle end,) drops down, by which means the travelling motion is stopped. The twisting motion would also be stopped, were it not, (as will be seen from the figure,) that though the catch-box 14 is thrown out of geer with the sheeve *s* on the upper side, the catch box 25 will be at the same instant, and by the same movement, thrown into geer with it on the under side, so that the twisting motion continues. The under side of the catch-box 13, being thrown out of geer with the pinion *h*, (which stops the travelling motion,) the upper side of it will be at the same instant, and by the same movement, thrown into geer with the worm 27, which consequently gives motion to the screw-wheel 28; the arm 29, (which it will be recollected is then hanging down,) is also carried round with the wheel; and when it comes in contact, having nearly made one revolution with the swinger 19, it forces it down, and by this means puts the catch-box 25, as well as its own, out of geer, and causes the whole of the machinery to stop. The use of the spring 31, pressing against the back of the arm, is to cause it to force, as soon as the catches 13 and 25 are out of geer, the swinger 19 a little further down, which it will then be enabled to do, in consequence of the resistance against it being decreased; the object of this is to prevent any jarring of the catches when in that situation. The spring is prevented forcing too far by a stop. Another method of forcing the swinger thus much farther down may be adopted, by fixing a pin or fang to project from the framing of the machine, so as the end of the spring above mentioned may come in contact with it a little before the time when the arm begins to force down the swinger, in order that the arm may be relieved from the pressure of the spring until the arm has forced the swinger down nearly to the point of sending the catches out of geer, at which time the end of the spring, having got free of the pin, comes with a sudden blow against the back of the arm, and thus sends down the catches clear of those with which they were in geer; the spring in this case also is prevented from forcing too far by means of a stop. The time the screw-wheel is in going round is the time allowed for the after-twist: but should one wheel not allow sufficient time for the purpose, the motion may be farther decreased, by any usual and well-known means, and change wheels may be applied to suit the different kinds of yarn.

In tempering the strands of all kinds of cordage, whether shroud, hawser, or cable-laid, it is well known that from various causes an inequality of tension between the different strands intended for the same rope takes place, and is most commonly apparent during or after the operation of hardening, some of the strands becoming too slack, others too tight, and consequently of unequal lengths, though originally they may have been of equal length, and have received the same twisting or number of turns by machinery of the most improved and perfect construction. In cases, therefore, where this inequality appears, the strands require to be rectified, by being brought to an equal degree of tension, in order that each may bear its equal portion of strain in the rope when made. The operation for effecting this object is commonly called tempering the strands; and the method in general practice is to give more twist to a slack strand, or to take twist out of a tight one, or to do both. In some rope-grounds where the machinery is driven by steam, or other considerable power, the method adopted is to give more twist to the slack strands, which is done by stopping the twisting of the tightest strand, by throwing its hook out of geer, and to keep it waiting in that position until the slack strands have twisted up to the same tension.

These methods in most cases are defective; because the strand to which more twist is given is thereby rendered less pliable, and is of smaller circumference; consequently it cannot top or lay up in the rope evenly and regularly with the other strands which have less twist; for the harder twisted one will in the rope sink inwards, and the others stand outwards and form more of a spiral round the harder twisted one, which will thereby have more than its proportionate strain in the rope to bear, and will also be least enabled, when under a strain, to stretch up, so as to avail itself of the assistance of the other, and by consequence must be the first to break. Should the inequality of tension be occasioned by any original inequality of thickness in the strands, the smallest one will, during the process of hardening, become the slackest, and in tempering by twisting it up to the tension of the tightest, the inequality of size will by that means be increased; for the more it is twisted, the still smaller in circumference, as well as shorter in length, will it become. But, supposing all the strands were originally of equal thickness, and that the inequality in tension proceeded entirely from an error in the original lengths; it is plain, that, by tempering according to the methods in question, (and no other methods, after the strands are fixed on the hooks, and the work has commenced, can, by any machinery hitherto in use, conveniently be adopted,) the same defective principle still applies, which, by causing one strand to be harder twisted, and consequently to become of a smaller size, and another to be softer twisted, and to become of a larger size, prevents the whole from jointly forming a regular and perfect rope, and to stretch equally when under a strain, as already described.

As a more convenient, accurate, and certain method, than any hitherto practised, appeared to be necessary, Mr Duncan invented and adopted a new mode of tempering the strands of all kinds of cordage, whether shroud, hawser, or cable-laid: the nature and general principle of which is, to cause any one strand-hook of the foreboard, or foreboard-machine, when the strand attached to it requires to be tightened, to recede from its corresponding opposite hook of the sledge or stranding-machine, to which the other end of the strand is attached; or when it requires to be slackened, to cause it to advance towards its corresponding opposite hook, thus bringing all the strands to an equal tension, without one strand-hook making more revolutions than another. And, what is of essential importance to this invention, the operation may be performed leisurely, as occasion may appear to require, either before, during, or after hardening the strands, without stopping the twisting, or other motions, or occasioning any interruption to them whatever; and with more ease, minute accuracy, and useful effect, than by any other method yet practised for the purpose.

In order more particularly to exemplify and illustrate this part of the invention, we have annexed engravings of the machinery which Mr Duncan has contrived and adapted for the purpose.

In fig. 481, A B C represent the upper part of the framing in which the machinery, placed at the foreboard, is fixed; C being the front of it, facing or looking down the rope-walk. D is a toothed wheel, receiving motion from any external machinery. This wheel drives the other toothed wheel E, and either of them can be changed to suit the speed of the motion required. The toothed wheel E is fixed upon the axis of, and gives motion to, the toothed wheel or fluted cylinder F, which cylinder drives the four pinions 1, 2, 3, 4, whose axles, to the hooks of which the rope strands are attached when twisting and tempering, are the four strand-hook spindles *a*, *b*, *c*, *d*. To answer the purpose of the invention, the strand-hook spindles, besides having the rotative or twisting motion which we have already described, are so contrived, for the tempering of the strands, that any one or more of them may, while the twisting motion is or is not going on, be made to slide, in a horizontal direction, parallel with the axle of the cylinder F, along any part of its length, either backward or forward, as shall now be explained. The strand-hook spindles having to slide, as has been said, in a direction parallel to the axis of the cylinder, are of course placed in that direction, and so as their pinions may pass each other. The positions of these pinions round the cylinder are seen in fig. 482, which represents a front view of the machinery; the same references in each figure being used to denote the same part. As all the four strand-hook spindles, with their accompaniments and immediate connections, are precisely the same, a description of one will be sufficient; we will therefore take the spindle *b*, in fig. 481. G H is a long or male screw, a few inches longer than the cylinder, upon which is fitted the nut or female screw, *e*, having spokes or arms, to admit of it being turned by hand. Joined fast to this long screw is a head-piece or claw *f*, within which a carrier or step is fitted, and in which the adjoining end of the strand-hook spindle revolves. Two collars, *g* and *h*, fitted on the spindle, one on each side the step, cause the spindle to accompany the long screw, either backward or forward, when moved by turning the nut *e*, the rotative motion of the spindle going on at the same time if required; *i* and *k* are two steps or guides, fixed on the cross framing B and C, through which the spindle may pass and repass, and in which it also revolves; *l* is a carrier of the same description, fixed on the cross framing A, through which the long screw may pass and repass, but without revolving. Fast upon, and projecting from the head-piece *f*, and consequently accompanying the long screw and spindle in the sliding movement, (see the side view, fig. 483,) is the tongue *m*, the end or point of which is fitted to pass along during that movement in a slot in the rail *n*, fixed parallel with the long screw and spindle, between the two cross bearers A and B.

The object of this contrivance is to prevent the spindle, (one end of which, as has been shown, revolves within the head-piece of the long screw,) from carrying round the screw along with it, and to keep the screw and its head-piece at all times steady, and in a direct line with the spindle. For the purpose of keeping the long screw stationary in the situation to which it may have been last set, the pull of the strand on the hook, (by pressing and abutting the screw-nut *e* against the back of the carrier *l*,) will always be found to be sufficient. The diameter of the cylinder F may be about two feet, and that of each of the four pinions 1, 2, 3, 4, about one foot, more or less, according to the speed desired, and the discretion of the mechanic. The pitch of their teeth should be the same as that of the teeth of the cylinder. The length of the cylinder should at least be equal to the greatest difference or inequality of length ever likely to take place between the slackest strand and the tightest strand intended for the same rope, previous to, or during, the operation of hardening, when they are both brought to an equal tension by tempering according to this method. The inequality of length, or, in other words, of tension, which takes place in the strands during the process of hardening them, is generally found to be in proportion to their circumference, and is more in a set of the large strands than in the small. In rope-walks, therefore, where cordage of the largest size is manufactured for the use of his Majesty's navy, the length of this cylinder should not be less than four feet; but Mr Duncan has found, by experience, in manufacturing cordage for merchantmen of the greatest burthen, that few cases occurred where it was requisite for the length to be more than three feet. In rope-walks where cordage on the common principle is manufactured, some additional length is necessary. Each of the four pinions is fastened upon the middle of the length of its strand-hook spindle. Supposing, therefore, that the pinion 2 should be set so as to be exactly at one end of the cylinder next to the cross framing B, it must be enabled to slide along to the opposite end next the cross framing C, and also back again to B; for this purpose the spindle must always be kept in its steps or carriers, *i* and *k*, which support it, and in which it both slides and revolves, and therefore it requires to be double the length of the cylinder, besides an additional length equal to the spaces in its passage occupied by the necessary steps, framing, clearances, &c. The length of the long screw G H, and of the rail *n*, are each the length of the cylinder, and correspond with, or are a few inches longer than the sliding distance, to allow for steps, &c. as above. It has been shown, that the cylinder drives the four strand-hook spindles, and that any one of them can be moved by means of its screw, either backward or forward, without interrupting its own rotatory motion, or the rotatory motion of any of the others; the teeth of the pinions being for this purpose kept in geer with, while at the same time they are made to slide along between, the teeth, or in the flutings of the cylinder.

Suppose, then, that the strands are attached to their respective hooks, and the pinions set so as to be all at an equal distance from each end of the cylinder, and all the strand-hook spindles going round, twisting and hardening the strands, the operation of tempering is performed merely by turning round by hand, as often as required, any one or more of the screw-nuts either way about, as the case or cases may require, according as any one or more of the strands require slackening or tightening for bringing them all to an equal tension. Thus, in order to slacken a tight strand, its hook must be advanced forward further from the front of the framing C; and in order to tighten a slack strand, its hook must be drawn in, towards the framing.

Fig. 484 is a side view, representing some variation in the machinery for effecting the sliding movement of the strand-hook spindles on the same principle, and answering the same purposes, as the plan in fig. 481, already described. After the full descriptions and explanations already given, a very short account will be sufficient to make this fully understood: *b* is a strand-hook spindle, similar to those in fig. 481, excepting that the pinion 2 is not made fast upon it, because it has to pass or slide through the axle hole of the pinion. In order that the spindle may at the same time revolve with the pinion, the slot 10 is cut upon one side of the spindle, (the length of the slot being the sliding distance,) which slot receives a feather or key in the axle hole of the pinion, through which the slotted part of the spindle is to pass and repass, as occasion may require, the feather always remaining in the slot to carry round and give the rotatory or twisting motion to the spindle. The parts *f*, *g*, and *h* are exactly the same as the parts which have the same characters in fig. 481. I is a rack, (to answer the same purpose as the long screw in fig. 481,) which the pinion *o*, by means of the handle *p*, moves either backward or forward. The ratchet-wheel, *q*, and its catch, hold the rack and pinion stationary in the situation to which they may be set; *i i* and *k* are the steps in which the spindle revolves, and through which it also slides; *r r* are two rings or washers, loose upon the spindle, between the steps *i i* and the pinion 2, intended to qualify the friction during both the sliding and the rotatory operation of the spindle; *s* is a guide or step for the rack to slide in, made square at the bottom, which renders the tongue and slot, shown in fig. 483, unnecessary. The wheel K, receiving motion from any external machinery, drives the pinion 2. Change wheels, for varying the motion, may be applied to this method in the same way as in fig. 481.

From what has already been described, it will appear, that the strand-hook spindle may, by means of the rack I and pinion *o*, be drawn or slided either backward or forward, through its pinion 2, without interrupting its rotatory motion; the pinion 2 always keeping in geer with the wheel K, by which it is driven, and which latter may receive its motion from any external machinery. Referring, therefore, to the former description, it will be evident, without further explanation, by what means the stands are to be tempered by this variation in the machinery.

The reader will observe that there are two principles by which the strands of cordage may be tempered or brought to an equal tension; the one by causing any one or more of the strand-hook spindles either to advance or recede, whereby an equal tension will be effected without one spindle making more revolutions than another; and the other, that of causing any one or more of the strand-hook spindles to be at rest while the others are revolving; whereby an equal tension may be effected by an unequal number of revolutions. If one of these two principles only is to be adopted, Mr Duncan prefers the former, as being generally more appropriate and effectual. As, however, it sometimes occurs in practice, that the application of the one principle, sometimes of the other, and sometimes of both, proves to be the most proper and effectual remedy, Mr Duncan has invented a still more perfect method, by which either or both of the principles may be practically applied in one set of machinery. This object, which had never, we believe, been before accomplished, is effected merely by applying to either of the two varieties of machinery before described, an additional apparatus, so that all kinds of cordage-strands may thereby be tempered, either entirely, by the principle of causing any one or more of the strand-hook spindles to advance or recede; or entirely, by causing any one or more of the strand-hook spindles to be at rest while the others are revolving; or partly by the one and partly by the other, according as the original cause occasioning the inequality of tension in the different strands may point out; the whole, or any part, of the operations going on, either together or sepa-

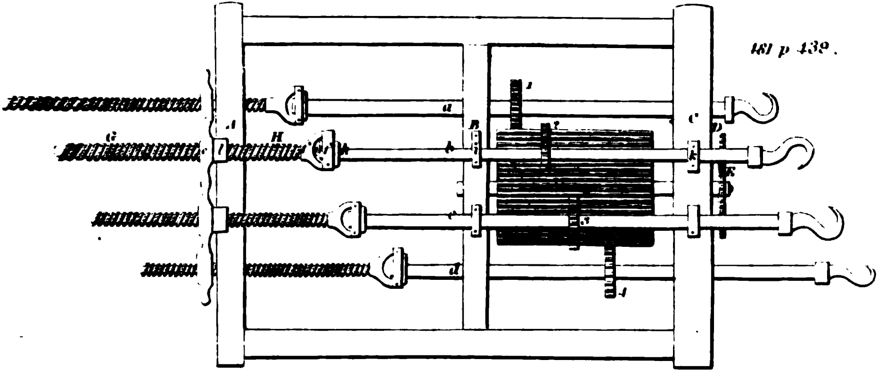
ROPE MANUFACTURE

From 481 to 484

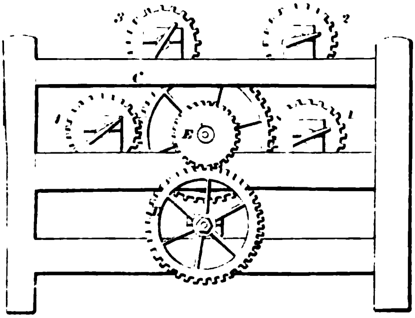
Pl 70

Tempering

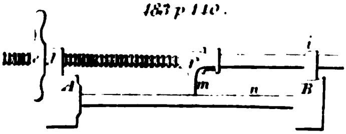
481 p 439.



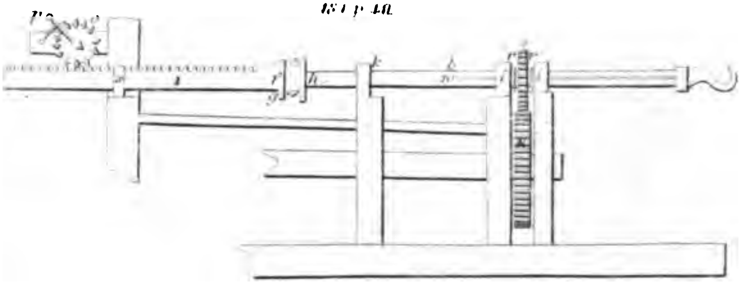
482 p 439.



483 p 440.



484 p 440.



rately, as may be found convenient, without interruption to each other.

Fig. 485 is a plan showing the additional machinery for tempering, by combining the two principles as adapted for the first described machinery, represented in fig. 481. The difference between the machinery of fig. 481, and that of fig. 485, consists chiefly in the latter having its pinion 2 loose upon the twisting spindle *b*, but confined between two collars, which are fast upon the spindle. The reason of the pinion running on a loose round is, that it may be either put in or out of geer with the spindle, by means of the catch-box *t* and lever *u*. The catch-box has a slot, fitting a feather on the spindle, in order that it may revolve with it, as well as slide in or out of geer, when moved by the lever. The ratchet-wheels *v* and *w* are fast upon the spindle, one having teeth cut the reverse of the other, that either of the two palls *x* and *y* may, when the spindle is thrown out of geer with the pinion, prevent the strands from untwisting, as otherwise the spindle would be at liberty to be acted upon by the force of twist already in the strand. The pall *y* is flat toward the point for holding against the ratchet-wheel *w* for a right-hand twist, and the pall *x* is hooked towards its point for holding the wheel *v* for a left-hand twist. So far, this apparatus would serve the purpose either of keeping in geer, or stopping the rotatory motion of the spindle, provided it were not also required to perform the sliding movement. In order, therefore, to complete the apparatus for both these purposes, the arm *z*, fastened to the claw or head piece *f*, and forming one piece with the long screw G H, stretches alongside, parallel with the spindle, so that its other end is nearly opposite to the pinion, where it is furnished with two ears, having each an eye or ring, 7 and 7, fitting easy upon the round iron rod 8; which rod is fixed parallel with the spindle, between the cross framing B and C. The step 9, on the cross framing B, serves as a guide for the arm *z*. It is necessary that the distance between B and C should be as much longer than the distance in fig. 481, as the length taken up or occupied by the catch-box and ratchet-wheels. The spindle also will require this additional length. The arm *z*, during the sliding movement, has to conduct with it, along the rod 8, the lever *u*, and the two ratchet palls *x* and *y*, the rod serving them also as a guide during the sliding movement, and at all times as an axle. Though the pinion 2 is always in geer with, and carried round by, the cylinder F, fig. 481, yet the spindle only goes round when put in geer with the catch-box by the lever; therefore the rotatory motion of the spindle may at any time, and for any space of time, be stopped, for the purpose of causing the twist of its strand to cease, while at the same time the other strands are twisting up. Though only one spindle is here spoken of, it is evident that all or any of them may, from being furnished with the apparatus now described, be made either to give, or cease from giving twist, while any one or more of the spindles either may or may not, as required, be performing the sliding movement.

Fig. 486 is a side view, showing the method adapted for the second described machinery, as represented in fig. 484, the apparatus in this case applying to the narrow wheel, and that in the former case of fig. 485, applying to the wide wheel or cylinder F. The difference between the one and the other is, that the spindle and pinion in fig. 485 slide together, as in fig. 481, whereas in the figure now to be described the spindle slides through the pinion, as in fig. 484. The spindle *b* in this figure is similar to that in fig. 484, having a slot, to receive a feather, which is fixed in the catch-box *t*. The pinion 2, which is always in geer with the wheel K, is fastened on the bush 11, running loose upon the spindle *b*. This bush, being furnished with the collar 12, serves by means of its revolving in the cavity 13, adjoining the step *i*, to keep the pinion in its proper place, during the spindle's sliding movement: *i* and *k* are two steps, answering the same purpose as those of the same characters of reference in fig. 484: *v* and *w* are two ratchet-wheels, fast to each other, but not fast on the spindle, having a feather, fitting the slot of the spindle, in order that they may hold it fast when occasion requires, and that it may pass and repass through them during the sliding movement. These ratchet-wheels are furnished with their two palls *x* and *y*, altogether answering the same purpose as those described in the former fig. 485. The catch-box *t*, having also a feather, fitting the slot, is furnished with a lever, (not shown in the figure,) answering the same purpose as the one marked *u*, in fig. 485; but to suit the present case, it works on a stationary pivot, fixed to the framing of the machine. The two ratchet palls also work on pins fixed to the framing; and their wheels *v* and *w* being furnished with the rim or fencing 14, are kept always opposite to the palls, by means of a bracket, (fixed to the framing, but not seen in the figure,) hollowed out to receive the rim. It will be evident, from what has here been said, that the operation of striking in and out of geer the rotatory motion of the spindle is performed exactly in the same manner, and also answers the same purpose as that described under fig. 485; and that the sliding movement of the spindle in both cases is performed in the same manner, and answers the same purpose, as described under figs. 481 and 484, either one or other of the methods, under figs. 485 and 486, combining the two principles of tempering strands in the manner previously pointed out.

Though in the first-described machinery it has been shown, that the sliding movement of the strand-hooks may be effected by means of a male and female screw, and in the second-described machinery by that of a rack and pinion, yet it will be seen, that either means may with equal propriety be applied to either machinery. And a competent mechanic, from what has been described, will easily perceive that any other power, such as that of a lever, weight, or rope and pulley, or one or more of them combined, may be applied for the same purpose, though in the first preference be given to the screw, and in the next to the rack.

The next part of the invention to be described is a new method of regulating both the backward and forward travelling movements of any sledge or other locomotive machine that is or may be used in a rope-walk. The backward movement of the stranding sledge, or the retrograde movement of that machine towards the bottom of the rope-walk by which strands are drawn out, in rope-walks where the improved or patent principle of rope-making is adopted, has hitherto been effected by means of a rope applied in different ways for the purpose. In some cases the rope is made to haul the sledge backwards, by fastening one end of it to the sledge, and the other round the capstan or barrel, at the bottom of the rope walk; and in other cases the rope is stretched tight along, and made fast at each end of the rope-walk, and two or more doubles or bights of it passing round and grasping the same number of grooved binding sheeves in the sledge, which revolve by connection with the rotative motion of the strand-hooks, from which the other motions are derived: thus the sledge works itself backwards along the rope.

The great object to be attained in regulating this backward motion is, to cause it always to preserve a certain speed in a given ratio with that of the rotative motion, in order that the strands may always receive the degree and uniform distribution of twist intended. But in whatever way a rope has hitherto been applied for that purpose, the object has never been effectually attained, nor the operation conveniently performed, because, from the elasticity and specific gravity of the rope itself, extended along the whole length of the rope-walk, it has been found impossible to keep it accurately stretched, and equally tight from one end to the other, so that when the sledge is in motion, particularly when first struck into geer, it pulls up the slack of the rope from the bottom of the rope-walk, and its retrograde motion is thus retarded in proportion as the rope may stretch, slip, or give way.

The retrograde motion loses therefore its relative speed commensurate with that of the rotative motion of the strand-hooks, which have in the mean time, without interruption, continued to put twist into the strands. Instances are not unfrequent where they have been twisted to such a degree as nearly to break them asunder before the rope could be tightened sufficiently to cause the sledge to move on at its proper speed; and, on the whole, it is obvious, that by the present method of drawing out the strands, they can neither receive their proportionate twist nor the distribution of it. The labour required in applying the rope is besides extremely inconvenient and troublesome, because it requires to be first fixed to the sledge, or round its binding sheeves, at the top of the rope-walk, then tightened, and afterward disengaged at the bottom, on every single occasion of drawing out a strand or set of strands. The plan also is expensive, because the constant wear and tear is considerable, and requires the rope to be frequently renewed. An iron chain may indeed be applied for the purpose, and though not requiring to be so frequently renewed, it is equally objectionable with the rope in most other respects, and on some accounts more so. The forward movement of the stranding, topping, and dragging sledges, is that slow progressive movement necessarily required towards the top of the rope-walk by the shortening or shrinking up of the strands in twisting, while forming on the common principle, and of the strands or cordage, either common or patent, whilst hardening and topping. It will readily be seen, that this movement should also be uniformly regular, in a given proportion to the twisting motion, and that the travelling distance should be neither more nor less than the length the strand or rope ought to shrink up. According to the usual method, a number of press barrels or weights are placed on the stranding or topping sledge, or on a drag sledge, attached to their tail end, to serve as a resistance against the pull of the strand or rope when shrinking up. But as the quantity of weight to be applied is to be varied or proportioned to the size of the strand or rope, and degree of twist required, and as the friction of the drag on the ground is greater on some parts than on others, the operation, depending on criterions so uncertain, must be attended with a great degree of irregularity, both with regard to the sledge sliding faster or slower, and also with regard to the whole length to which, eventually, it may be dragged; thereby occasioning a proportionate irregularity, both in the distribution and total quantity of twist or lay in the strands or rope, corresponding with their length.

The object, therefore, of this invention, with regard to the *backward* movement, is to cause the sledge, or any other locomotive or travelling machine used, or that may be used, in a rope-walk, to travel and recede down the walk at one uniform speed, such as shall be predetermined as proportionate with the rotatory speed of the twisting hooks of the machine, so as to cause the twist to be uniformly regular throughout each operation. And the object of this invention, with regard to the *forward* movement, is, to cause the sledge, or other movable machine, to which any kind of strand or rope may be attached, for the purpose of being formed, hardened, or laid, to travel slowly, and advance up the walk, during the operation, at one uniform predetermined motion, and precisely the length or distance assigned to it, equal to that which the strands or rope ought to shrink up in the operation.

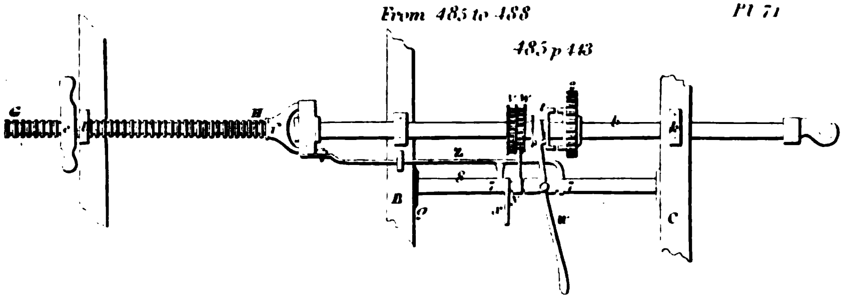
Having stated the object of this part of the invention, we shall now proceed to show that the nature and fundamental principle of it, and the means for accurately and conveniently attaining all the objects in view, both with regard to the backward and forward movement, consist in a rack, or rack-way, of cast-iron, or other suitable material, laid down and fixed upon and along the rope-walk, from one end of it to the other, parallel with a rail-way, upon which the stranding sledge, or any other sledge or locomotive machine, is to travel. The teeth of the rack-way are of the same pitch as the teeth of a wheel whose axle is in the machine. The motion of this wheel being given and governed by the other motions in the machine which turn the

ROPE MANUFACTURE

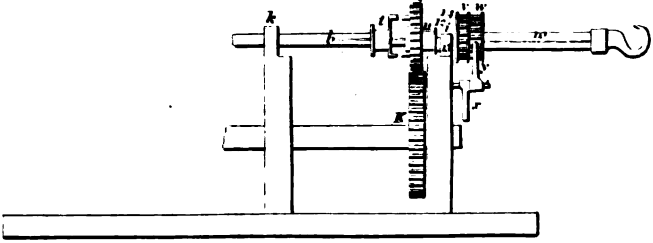
From 485 to 488

Pl 71

485 p 443

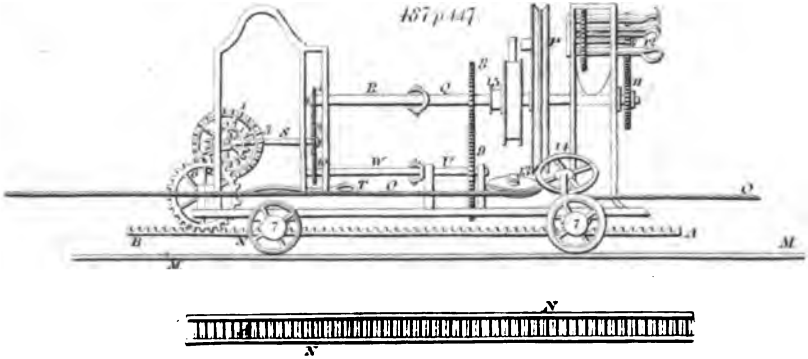


486 p 443

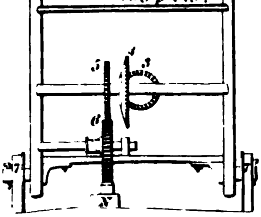


BACKWARD & FORWARD MOVEMENT

487 p 447



488 p 448.



twisting hooks, the travelling speed of the machine, whether working backward or forward, becomes at all times uniform, and in a given certain ratio, with the speed of its twisting motion; for the whole machinery being composed of geer and toothed work, no part of it is liable to slip or yield. The required speeds, both of travelling and twisting motions, are adjustable by change wheels, to suit each other in that machine, as well as in any other machine or machines that may be employed in one and the same operation. The whole machinery may be driven by an endless rope, receiving its motion from external machinery at the top of the rope-walk, or by any other means in use for driving locomotive machinery; for, we need scarcely observe, that it is not necessary, for the purpose of producing accurate work, that the motion which governs all the others should be uniform, because, whether the original motion be quicker or slower at one time than another during the operation, the motions dependant on it will still keep their proportionate speed. The only difference will be in the time in which the work may be finished. We have mentioned the particular cases in which this part of the invention is more essentially useful; but Mr Duncan claims the application of the rack, in manner described, as an invention subservient to every purpose, in any stage or process of rope-making, for which regularity of travelling motion to any machine, either backward or forward, in a rope-walk or elsewhere, may be required.

In that part of the drawing entitled "Backward and Forward Movement," fig. 487 represents the side view of a travelling sledge, or locomotive machine, of the description, and for the purposes referred to, moving on the railway M M. A B is a side view of the rack-way laid down and fixed on the wood sleeper N N, or other suitable material, supposed as extending from the top to the bottom of the rope-ground. This machine is represented as driven by the endless rope O; 13 and 14 are two guide pullies, to conduct the rope in going on and coming off the large sheeve or grooved wheel P, round which that rope, (driven by external machinery, and running from top to bottom to the rope-ground,) passes, by which the first movement in the sledge is given. This sheeve, giving motion to the spindle or shaft Q, and being coupled with the shaft R, turns the pinion 1, which drives the pinion 2, upon whose shaft, S, is the small bevel-wheel 3, driving the large bevel-wheel 4, upon whose shaft again is the spur-wheel 5, driving the other wheel 6; which last wheel works in the rack-way. This wheel is not fast upon its shaft, being capable of sliding thereon, for the purpose of being put in and out of geer with the rack by means of the lever T. The machine travels on the railway on four truck-wheels: the two shown in this figure are marked 7. The pinions 1 and 2 are changeable, to suit the different travelling speeds required.

So far as has been now described refers only to the backward movement of the machine; which movement, it must be understood, is in the direction along the rack-way, as from A towards B. The contrary, or *forward*, movement is of course in the direction from B towards A, and is effected by giving a reverse turn to the wheel 6, which works in the rack-way. The necessary machinery for this purpose is the small pinion 8, on the shaft Q, driving the wheel 9, on the shaft U, which last shaft, and the one coupled with it, W, lie parallel with, and extend to, the end of the shaft R, in order that the pinion 10, fixed on the end of W, may, when required, work in the pinion 2. The shaft S then becomes common to both the pinions 1 and 10, and may, as required, be driven by either the one or the other, the pinion 1 being for the backward movement, and the pinion 10 for the forward movement, one of them therefore must be out of geer while the other is in geer. The figure shows the pinion 10 as out of geer. But supposing it to be in geer with 2, and the pinion 1 out of geer with it, the effect is, that a contrary motion is given to the wheel 6, which works in the rack-way, by means of the intervening wheels 3, 4, and 5, before described. The twisting motions of this machine are produced by the shaft Q being continued to the front of the machine, where the wheel 11, on the end of the shaft, drives the counter-wheel 12, from whence the required degree of speed is given to the twisting-hooks. From what has been before described, it will be seen that the backward and forward motions of the machine are produced by means of the wheel 6 working in the rack-way either way about as required. As, therefore, any predetermined quantity of twist may be given by means of the change wheels 11 and 12, whilst at the same time the machine may be made to travel at any given predetermined speed, either backward or forward, by means of the change wheels 1, 2, and 10; and as the twisting, as well as the travelling motion are driven by one and the same impulse, originating in the machine at the grooved wheel P; they must always preserve a relative speed to each other in such proportion as may be assigned to them. A forked lever, clasping on the catch-box 15, serves either to put in or out of geer all the motions of the machine, excepting that of the grooved wheel P.

Fig. 488 is a view of the back end of the same machine, showing as much of the machinery as is necessary for understanding it. The same characters of reference used in fig. 1 denote the same parts in this.

Fig. 3 is a plan of part of the rack-way. A is the rack; and N N is the wood sleeper upon which it is fastened. The forward motion of the sledge is a remarkably slow movement; the speed of the wheel 6 therefore requires to be considerably reduced. The wheels shown in the figures will not reduce the motion sufficiently slow to suit every possible occasion; but enough is shown to enable a mechanic readily to produce any degree of motion that may be required.

All or any part of the machinery which we have described may be driven by the power of steam, water, wind, or animals.

In the course of describing the different machines, and their component parts, adapted for the various purposes of the invention, we have seldom taken notice either of their dimensions or of the materials of which they may be made, because no fixed rules can be given: but any competent mechanic, from what we have shown, will be enabled to apply such sizes, and use such materials, as may be suited and proportioned to the nature and design of each machine, and to the power which is to drive it, particularly when we add, that the figures in the plates marked "Tempering, and Backward and Forward Movements," are made out on a scale $\frac{3}{4}$ of an inch to a foot, and that the dimensions there given are such as may with effect be applied in practice.

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